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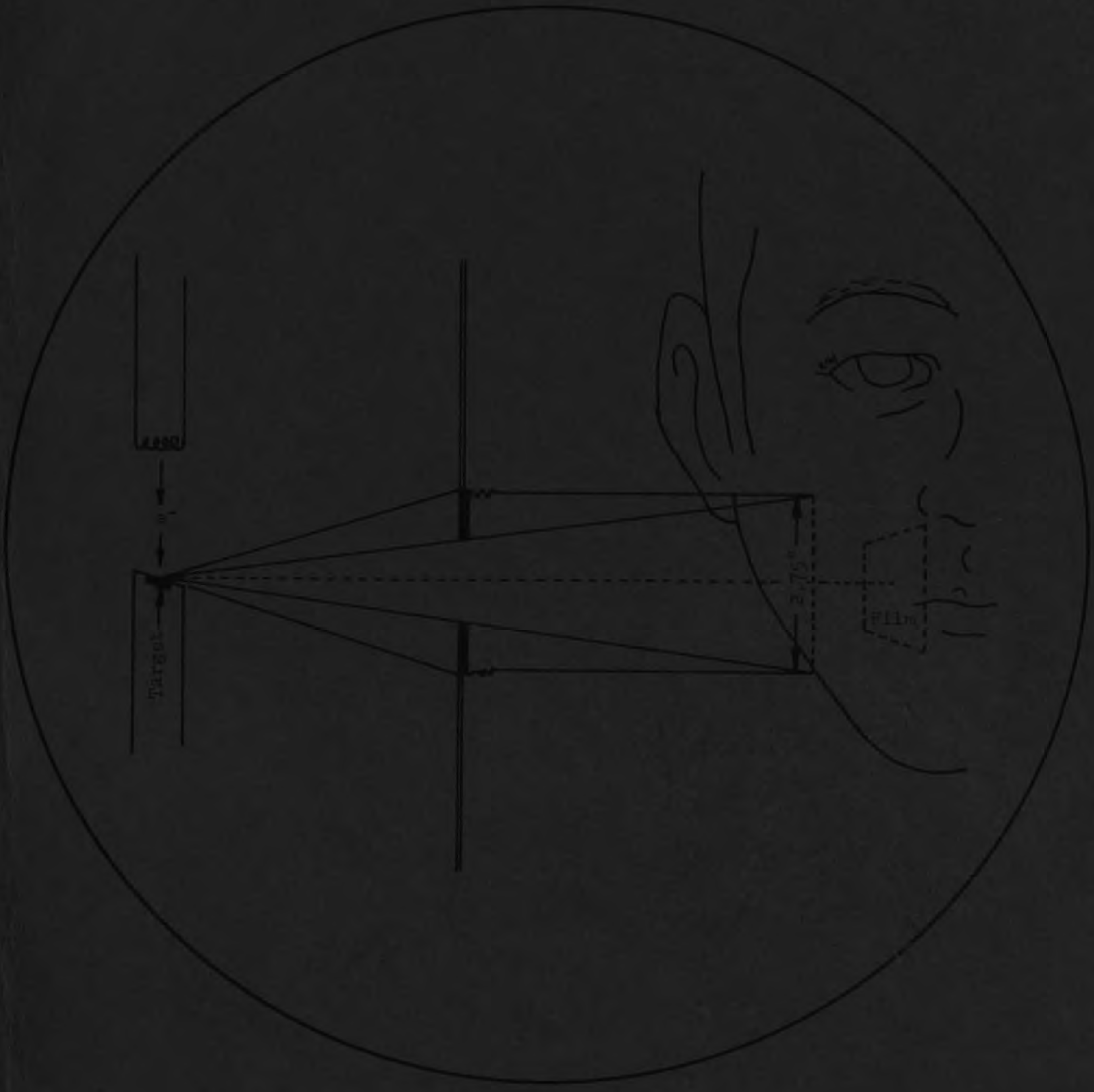

State of California
DEPARTMENT OF HEALTH
RADIOLOGIC HEALTH SECTION

DENTAL LABORATORY RADIOGRAPHY

by:

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DENTAL LABORATORY RADIOGRAPHY

FOREWORD

THE NEED FOR RADIOLOGIC TECHNOLOGY CERTIFICATION

History

Since the earliest time of man, the use of any source of energy has always required that it be handled with suitable knowledge and respect for its hazardous potential. Such was the case with fire, thousands of years ago, as well as with steam, explosives, electricity, X rays and, most recently, nuclear energy, as well as lasers and other forms of non-ionizing radiation.

X rays were discovered by Wilhelm Conrad Roentgen, a German physicist at the University of Wurzburg, on November 8, 1895. Even during the first year of its discovery, the X ray's side effects began to be noticed. A colleague, Emil H. Grubbe, noted an irritation on his hand which resulted from radiation while manufacturing and testing vacuum tubes. Up to the time he died in 1960, he underwent 83 operations to overcome the tissue destruction and degradation resulting from 65 years of exposure.

Early in 1896, M. I. Pupin, of Columbia University in New York City, made a radiograph, and C. Edmond Kells, a New Orleans dentist, constructed his own apparatus and produced the first intraoral radiograph. The subsequent death of Dr. Kells has been attributed to overexposure to X radiation.

The distinction of pioneering in the science of radiation protection is generally accorded to Dr. William Rollins (1852-1939), a Boston dentist who also had a medical degree. If his early and continuing advice on radiation had been followed, a great deal of human anguish would have been avoided!

As early as 1896, Thomas A. Edison made the first fluoroscope using calcium tungstate. However, he discovered that the X rays had an adverse effect on an assistant, making his hair fall out and ulcerating his flesh. In an article in *Century Magazine* which reported the harmful effect of the X ray, Edison stated: "I then concluded it would not do, and that it would not be a very popular kind of light, so I dropped it."

In 1899, John Dennis, a newspaper reporter, recognized the need for radiation protection and certification. Before the Seventh District Dental Society of New York he declared, "It is my candid judgment that the time has now arrived when the abuse of this God-given energy should be controlled . . . that no living human being should be subjected to the Roentgen energy excepting by those who have established their competence to use it with absolute safety. I am aware that this contention will not pass unchallenged . . ."

In 1913, the National Bureau of Standards set up a program to standardize radium for medical purposes. In the following year, the first death from cancer attributed to X rays was recorded. In 1925, Mutscheller presented a concept of dose which may be tolerated for a prolonged period of time without causing injury; he expressed it in terms of a fraction (0.002-0.01) of the erythema dose. The tolerance dose associated with such criteria could vary widely between individuals and be in the neighborhood of 100 roentgens (R) per year.

In 1925, the International Commission on Radiological Units and Measurements (ICRU) was established under the auspices of the First International Congress on Radiology. Three years later, ICRU adopted and defined the "roentgen" as a unit of X-ray dose, thus providing the world for the first time with a common means of measuring X radiation in terms of the same unit. During the same year, the International X-ray and Radium Protection Commission was established; subsequently, it became the Internationsl Commission on Radiologic Protection (ICRP). Today, the World Health Organization (WHO) utilizes both ICRU and ICRP as technical advisors in the field of radiological units and measurements.

During the 1930's, the incidence of radium poisoning in workers painting luminous dials pointed out the need for internal radiation exposure standards. It also provided information and procedures for calculating a permissible or acceptable dose for humans.

Over the following decade, radiation protection appeared to be a problem of purely academic interest except to a relatively small number of concerned people who recognized the real dangers that were almost certain to arise as radiation uses increased. These individuals actively "preached the gospel" of radiation protection. Their activities undoubtedly prevented massive damage to the entire human race during the early 1940's when the Atomic Era opened with a large-scale demonstration of the first sustained nuclear fission reaction during World War II.

In the early 1950's, the commonly-used shoe-fitting fluoroscope was outlawed for shoe stores. Section 638 of the California Penal Code states that no X-ray fluoroscope, nor other equipment employing roentgen rays, shall be used for fitting footware or in viewing bones of the feet. However, the section exempted any licensed physician, surgeon or other person practicing a licensed healing art, or any technician working under the direct and immediate supervision of such a person.

In 1959, a bill was introduced in the California Assembly to require the State to regulate X ray usage to protect the public from radiation hazards. Although this bill did not pass, it was sent to the Assembly Interim Committee on Governmental Efficiency and Economy for interim study. In September, 1959, this committee conducted hearings in Los Angeles. These produced substantial testimony indicating that inadequately trained and even incompetent personnel were operating X-ray equipment in medical offices, and one witness described several cases of gross incompetence in this connection.

In February, 1965, the Senate Factfinding Committee on Public Health and Safety published a report which included a section on the subject of Certification of X-ray technicians, and which included arguments for and against the proposal. The argument against the proposal favored a voluntary system of control. It was tried from 1964 – 1969 and proved to be ineffective.

The argument in favor of establishing State requirements included the following points, among others: 1) Voluntary action by the medical profession is an unattainable ideal. Although partly self-disciplining, the medical profession does not have the power to require all medical practitioners to limit their use of X ray to the degree of their competence. 2) The present voluntary system permits an absence at the crucial time and place: when the patient is X rayed. The evidence was great that many medical practitioners were not qualified to do all kinds of medical X-ray work with maximum safety. Enactment of State requirements for X-ray machine operators would increase, not detract from, the doctor's responsibility.

This Committee came to the following conclusion:

> "Government regulation of radiation sources has been inaugurated in the realization that regulation is necessary to protect the living population and future generations from the hazard of unnecessary radiation. Because medical X-ray machines comprise the major source of public exposure, elimination of unnecessary medical radiation will greatly reduce the total amount of radiation and will enhance the public welfare. Regulation of equipment is not by itself sufficient; there is much evidence that improperly trained people can and do operate medical X-ray machines . . . "

The Committee also recommended that legislation be enacted to require the X-ray technician, the radiologic technologist, and the licentiate of the healing arts to demonstrate their competency in roentgenological technique and radiation safety.

Recent Legislation

The Radiological technology certification Act, which now appears as Sections 25660 – 25699.2 of the California Health and Safety Code, became law in 1969. Section 25660 of Article 1, Declaration of Policy, of this law states: "The Legislature finds and declares that the public health interest requires that the people of this state be protected from excessive and improper exposure to ionizing radiation. It is the purpose of this chapter to establish standards of education, training and experience for persons who use X rays on human beings and to prescribe means for assuring that these standards are met."

The regulations developed to implement the act provide for issuing certificates for the practice of diagnostic radiography and radiation therapy technology without limitation as to procedures or areas of application to those who fulfill all requirements, and issuing limited permits for diagnostic radiography for the categories of dental laboratory, chest, extremities, gastrointestinal, genitourinary, musculoskeletal, podiatric and photofluorographic chest radiography. Special provisions authorize a limited permit in dermatological X-ray therapy.

This legislation completes the establishment of a well-rounded radiological health program to regulate and control that part of the electromagnetic spectrum known as X rays. Schools for teaching permittees have been authorized and approved, technologists have been examined and certified or issued permits to administer radiation to specific parts of the human body, and licentiates of the healing arts have also been certified. Genetically-significant doses, mean bone marrow doses, and other organ doses are being reduced to serve the best interests of the public—as intended by the legislation.

ACKNOWLEDGEMENT

This Manual on Dental Laboratory Radiography has necessarily required the work of many people who have contributed to its contents in one way or another. The format of this volume was created by the staff of the Bureau of Radiological Health. Valuable suggestions were made by licentiates of the healing arts and radiologic technologists, to all of whom we express our appreciation.

Specific mention should be made of Radiologic Health Section personnel and others who contributed to material for this training manual: Amasa Cornish, Senior Health Physicist; Margaret Meredith, for her excellent illustrations and anatomical drawing; Mary Strecker, for her contribution in typing the copy and laying out the pages; Irene Lehr, Dr. P.H., for preparing contract; Charles Carlstein for his technical assistance and expediting activity; and Clifford Moore for doing a critique on the publication.

PREFACE

This manual, *Dental Laboratory Radiography,* has been prepared because of legislation requiring certification for practitioners of dental laboratory radiographic technology. One of the requirements for a limited permit in this field is that such practitioners must be familiar with methods of eliminating unnecessary exposure to all concerned.

Therefore, the manual is intended primarily to teach techniques and clinical procedures using appropriate radiation control and protection . . . how to produce top quality radiographs with minimum exposure to both the technician and the patient. To emphasize the extreme importance of this requirement, the manual includes a brief history of X rays and their development, together with discussions of the risk of improper or excessive irradiation, and methods to eliminate unnecessary radiation exposures.

As a skilled dental laboratory radiographer, you will be a member of a special group now recognized by California law. You will need a certain amount of graphic skill, manual dexterity and mechanical interest, and should be highly motivated in science, self-achievement and a desire to help your fellow man. In addition, self-discipline, integrity, tact, and the ability to get along with people of all ages – sick and well – will be essential.

To qualify for becoming a radiographic technician you must be at least 18 years of age and a high school graduate, preferably with study emphasis in science, mathematics and English composition. You should have initiative and the ability to work independently. Certainly, you will be doing rewarding and challenging work!

This manual describes the oral cavity, identifies the teeth and tissue structures, and delineates the various techniques employed in making dental radiographs. It also includes a list of other publications which we believe will be helpful in adding to your knowledge, plus a glossary of words frequently used in dental laboratory radiography.

Although this manual does not, of course, purport to cover completely every aspect of this complex field, we believe that diligent study of this material, in conjunction with your regular instruction, textbooks and laboratory activity, will be of major assistance to you in becoming a qualified dental laboratory radiographer. Since it will be updated continuously as new information comes to hand, this manual is published in loose-leaf form for your convenience.

If you have any ideas for improving or augmenting this manual, please let us know. Your suggestions will be welcome!

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DENTAL LABORATORY RADIOGRAPHY MANUAL

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DENTAL LABORATORY RADIOGRAPHY

I. GENERAL

A. Radiography as a Diagnostic Tool

The importance of radiography as a diagnostic tool was apparent almost immediately after the discovery of X rays by Wilhelm Konrad Roentgen in 1895. Physicians in both Europe and America were interested in Roentgen's report, and particularly in his X-ray pictures of the bones of living individuals. Within three months after Roentgen produced the first radiographic images of a human hand, C. Edmond Kells, a dentist, constructed his own apparatus for use in intraoral radiography. Another pioneer in dental radiography, Dr. Williams Rollins, foresaw both the dangers of the unrestricted use of X rays and the tremendous diagnostic advantages to be gained with the proper use of Roentgen's discovery.

The first radiographs, consisting of film emulsions painted on glass and covered with black paper, were crude in comparison with today's technique. Crude, also, was the X-ray source, which was an early vacuum tube known as a Crookes tube. Nevertheless, the exploration of the use of X rays as a medical and dental tool was already underway as early as 1896. The importance of radiography in diagnosis is now so firmly established that hundreds of thousands of radiographs are taken daily throughout the United States. This large quantity of the radiographs is witness to the indispensible importance of X rays in the modern practice of medicine and dentistry.

Compared with the amount sometimes required for radiography on other parts of the body, the quantity of radiation involved each time a single dental radiograph is taken is relatively small. However, it should be kept in mind that a full mouth dental X-ray series requires from 14 to 22 separate films. In addition, the average person usually has dental radiographs taken more frequently than any other kind. From the total accumulated radiation dose standpoint, therefore, it is particularly important that each dental exposure be kept at an absolute minimum. Ionizing radiation results in the alteration of living cells, and it is well established that such alteration can be harmful to human beings. We must approach the use of radiography not only with great respect for its diagnostic value, but also with a serious consideration of any possible detrimental effects.

B. Skill and Discipline

Having acknowledged that the use of radiation devices poses a potential health hazard, it is essential to exert every effort to minimize the risk. The most direct and effective means of controlling unnecessary radiation exposure may be achieved by using all available knowledge to develop the necessary skill and discipline for the proper operation and maintenance of radiation equipment. Many sources of information are available to the serious student, but time, effort and earnest application are required to become knowledgeable in any profession. No single source contains all the prerequisites for making an expert. Accordingly, this manual has included a list of other useful reference materials in Appendix B.

The instructions in this manual are concerned primarily with dental X-ray technology; however, this does not imply that the student should confine his attention to dentistry alone. He should also explore other avenues of X-ray technology and adapt such knowledge for the enhancement of his own skill. In the past, this knowledge has usually been gained through apprenticeship, and most clinical practice must still be acquired in this manner. There is no substitute for good supervision in clinical training and experience, and the intent of this manual is not to replace supervision, but to reenforce and amplify it.

C. Proper Equipment

Of the various sources of radiation for the purpose of radiography, the most practical and by far the most widely used is the X-ray tube. The X-ray tube is one element in a combination of electrical components which are designed and assembled in a unit which will produce X radiation. This apparatus is referred to as an X-ray generator, which is often called an X-ray machine. It is a high-voltage electrical system which produces electrons, energizes them to high speeds and directs them toward a metal target at the end of the anode. As the high speed electrons hit the target, the energy lost to them results in heat and X-radiation. Consequently, the target surface becomes the source of X rays. Only about one percent of the energy lost by the electrons results in X rays; the other 99 percent results in heat. The X-ray generator is a flexible and easily controlled source of radiation. These factors make it ideally suited for dental laboratory radiography. However, as mentioned above, it has been established that X rays may be a health hazard to anyone exposed to such radiation. Therefore, the operator of X-ray equipment must assume responsibility for its proper use and maintenance.

It is perhaps natural for the student or new technician to want to get his hands on an X-ray generator and test his skill in much the same way the camera fan wants to test the capability of his new acquisition. It must be borne in mind that the use of radiation equipment to radiograph people is governed by California state law. All X-ray generators in California must be registered with the California Department of Health and are subject to periodic inspection to determine compliance with regulations in the California Administrative Code, Title 17, Chapter 5, which is available for the asking.

D. Hygienic Considerations

Every person has some appreciation for cleanliness even though he may have no understanding of bacteriology. It is important not only to practice good sterilization procedures but also to practice them to the point that they are evident to the casual patient. When anyone is working within the mouth by hand and instrument, any laxity in common sense procedure may cause the transfer of communicable disease. The nose and mouth are particularly vulnerable in this respect. With a careless operator, harmful bacteria may be transferred either to the patient or from the patient. Note that in either case the operator controls the transfer so it is particularly important to exercise the utmost discipline in personal hygiene. Most of the discipline may be regarded as common sense and should begin with careful grooming. Obviously, hair and dress should be neat and clean with particular attention to the hands and finger nails. Hands and nails must be scrubbed before attending each patient and should be washed at the completion of most procedures.

Equipment sterilization is somewhat easier and for the most part may be accomplished with cold sterilization. A number of good products are available and details are easily obtained from any dental supply agency. It is important not only to use the proper type and concentration of sterilizing solution but also to insure the availability of an adequate number of instruments, or a rotation procedure, which will insure that each item remains submerged for the sterilizing duration.

Spray type sterilization solutions are available for large pieces of equipment such as the X-ray head (housing) and chair armrests. These are also usable on protective lead vests or aprons; otherwise use soap and water. In the latter instances it is not feasible to sterilize in the strictest sense but good hygienic discipline can arrest the transfer of harmful bacteria.

E. Ethics – Dental Laboratory Radiography

The practice of ethics for dental laboratory radiography is derived largely from the dental profession but is also influenced by established custom in medical radiology. Ethics in dentistry may often be defined as the moral obligation to render the patient the highest possible quality of dental service and to maintain an honest relationship with other members of the profession and community. This fairly accurately reflects the responsibility in laboratory radiography but of itself probably leaves something to be amplified.

Ethics are rules of conduct which have evolved through long custom and practice. Ethics resemble laws except that they are not as rigidly defined and the penalty for infractions is less direct. Ethics also differ from law in that they are voluntarily assumed by individuals having a common interest such as lawyers, physicians, dentist and X-ray technologists. The rules adopted are for the common good of their professions. Anyone wishing to practice in any of these professions understands that he will be required to conform to the ethics of his particular group or lose his acceptance by his peers. The interaction of individuals and groups, particularly in a large and complex society, requires that for the sake of their orderly progress certain rules be voluntarily accepted as a moral obligation. The key to answering questions on ethics is moral obligation.

In addition to ethics common to dentistry there are several specifics which probably merit emphasis for dental laboratory radiography:

1. Radiography is an auxiliary service and not only legally but ethically required to have its services initiated by a dentist or physician.

2. Technicians do not disclose findings in X rays to the patient either directly or indirectly. This is the sole province of the referring licentiate of the healing arts.

3. All persons involved in these complex professional relationships should refrain from making any disparaging comment. Those resorting to this tactic reflect very poorly on their own moral standards.

4. Every patient needs to be approached with some degree of compassion. As individuals, patients are varied and complex humans with fears, doubts, and even eccentricities which need to be handled tactfully.

5. Personal conduct should not adversely reflect on the group or profession. Unfortunate as it may be, the public and the news media often make group or class judgments based on the action of one person so it is particularly important to avoid controversial situations or issues.

6. Resolution of difference in ethical judgment should be made at the proper source. Most groups or societies have a prescribed procedure for handling differences. These procedures should be honored rather than resorting to public debate.

7. The most common problem in radiography arises from the patient's misunderstanding on the ownership of the radiographs. Legally, the radiographs are the property of the dentist or physician. The patient has not bought them even though he pays for the service. He, in fact, purchases a diagnostic service from the dentist. The dentist orders the X rays as part of his diagnosis and they become part of the patient's records. The patient cannot order the X rays and it is the responsibility of the dentist to dispose of these records as he sees fit.

F. Terminology

The technical language of the field of dentistry and medicine is based primarily on Latin and Greek roots that are combined to describe anatomical elements, disease conditions, and the various matters with which the dentist and physician must deal. The technician cannot be expected to master the vocabulary of dentistry in one easy lesson, but he should familiarize himself with the terms he encounters in the course of his work. This manual does not pretend to include a medical dictionary; however, the glossary (Appendix D) may save a few trips to the dictionary and should be a useful starting point in trying to become familiar with dental terminology and especially the terminology of radiography. The student should look for root forms that are used as prefixes and suffixes of his new vocabulary since acquaintance with the roots will often enable him to infer correctly the meaning of an unfamiliar word. Accuracy in usage requires knowledge of the correct spelling and the exact meaning of each word. Correct pronunciation is also important; but since it has not been practical to include guides to pronunciation in this glossary, the student will have to turn to the dictionary or to a knowledgable associate to cope with that phase of his education.

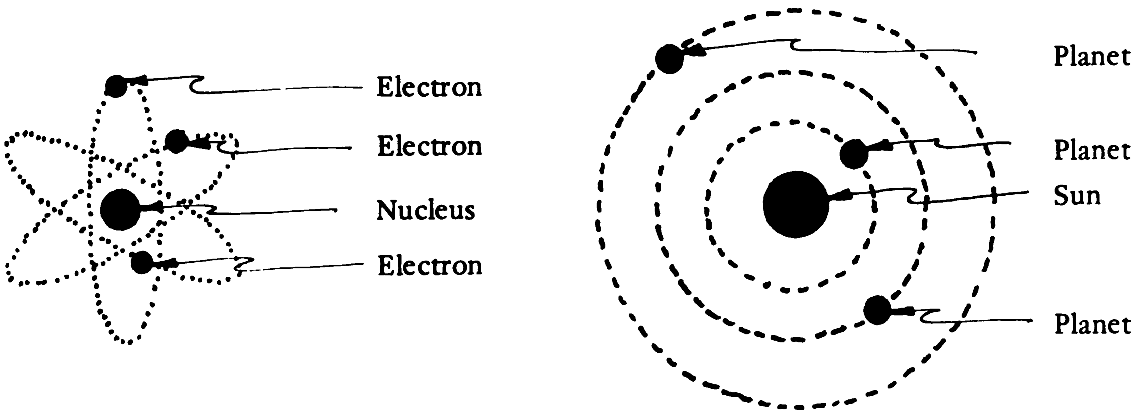
Most of the glossary definitions are reduced to simple phrases or sentences. Where more comprehensive definitions may eventually be required, the student might first concentrate on the simplest definition and then as time and experience permit the more detailed definitions may be mastered.

II. RADIATION PHYSICS

The world and all its constituents are composed of minute particles of matter called atoms. The word "atom" comes from the Greek word meaning "indivisible". At the time these particles of matter were named atoms, the Greek word was most applicable. However, there is no doubt that all of you now know that an atom is not the smallest particle of matter which has been identified. You also realize that the atom can be broken up into its component parts and that this process with the heavy elements enables us to acquire the energy which is commonly referred to as atomic, or nuclear energy.

A. Atomic Structure

If we were to take the 92 naturally occurring elements and the 13 additional elements which man has manufactured, and submit them to a bombardment with atomic particles, it would be possible to fragment the atoms of all the elements known at this time. If we collected all these fragments, we would classify them into three principal atomic components – namely, protons, neutrons, and electrons. If we were to use these principal components to produce atoms, they would be put together in the following manner: the protons and neutrons, which are the heavier particles, would be bonded together in a central portion of an atom, called the nucleus, with the electrons rotating about the nucleus in a manner analagous to the motions of the planets of our solar system about the sun (see Figure II–1).



An atom

The solar system

Figure II–1. The atom and the solar system.

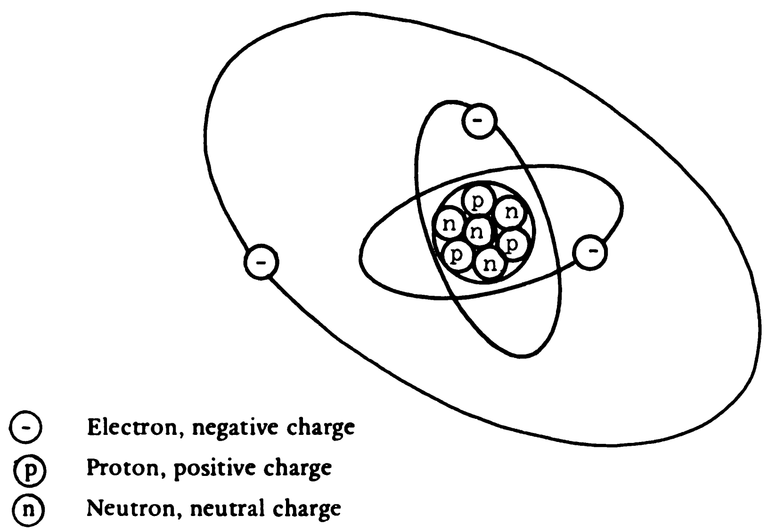
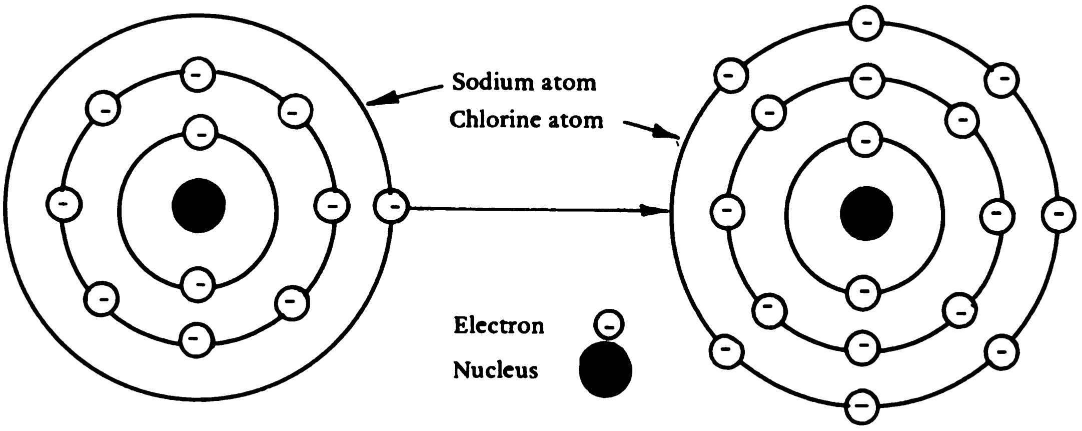


Figure II–2. Particles in a lithium 7 atom.

Electrons outside the nucleus are arranged in energy levels called shells, somewhat like the layers of an onion; and the energy that any electron possesses depends upon the shell or energy level in which it resides.



Na (sodium) atom loses electron becomes Na^+ ion
Cl (chlorine) atom gains electron becomes Cl^- ion
Na^+ ion + Cl^- ion $\longrightarrow$ NaCl (sodium chloride) molecule

Figure II–3. Sodium and chlorine atoms.

The transfer of an electron from one atom to another, as shown in Figure II–3, or the sharing of electrons of an atom with another, constitutes the chemical properties of an element – which is the same as stating that the electron portion of an atom is responsible for its behavior in the presence of other atoms and under a wide range of physical stresses, such as temperature, pressure, etc.

The central portion of the atom, namely, the nucleus, is the part which is responsible for radioactivity. Consequently, the generation and release of energy which is often called atomic energy should more properly be referred to as nuclear energy.

B. Ionization

An atom or molecule that has lost or gained one or more electrons is an ion. Therefore, the process of adding or removing one or more electrons from atoms or molecules is ionization. Our interest in ionization is that radiation of sufficient energy (this includes X rays) is able to bring about the removal of electrons from atoms and molecules and thus is referred to as ionizing radiation. Figure II–4 illustrates one process of ionization. It also illustrates an ion pair which is defined as a closely associated positive ion and negative ion (usually an electron) having charges of the same magnitude and formed from a neutral atom or molecule by radiation.

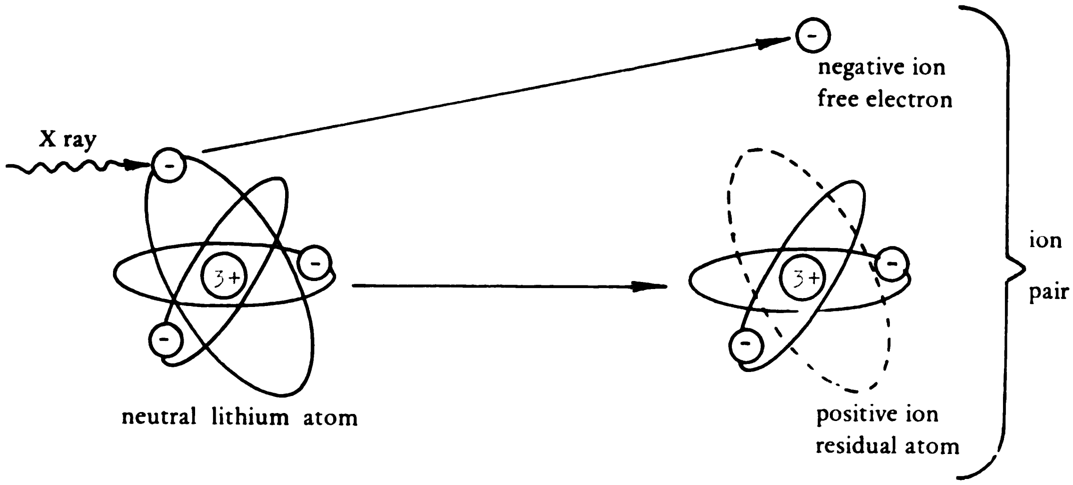
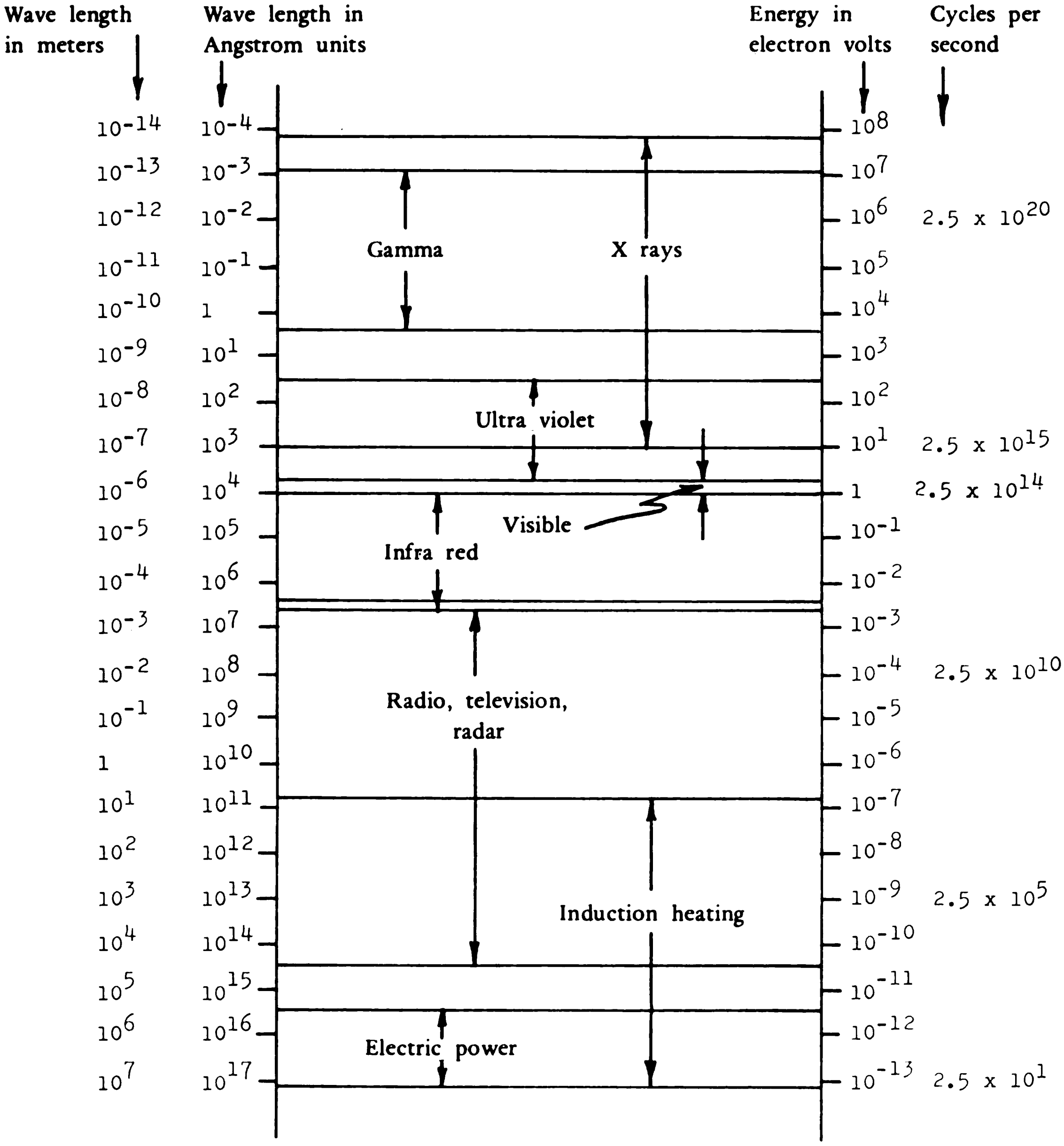


Figure II–4. Ionization. Before the X ray collides with the neutral atom, it has 3 negative (electrons) and 3 positive charges (protons). The atom is, therefore, electrically neutral. After the collision event, one electron is displaced from the atom, as shown, leaving the atom positive. The combination of the displaced electron and the residual atom is called an ion pair, and each segment an ion. This process is ionization. The neutrons in the nucleus are not shown.

C. Electromagnetic Radiation

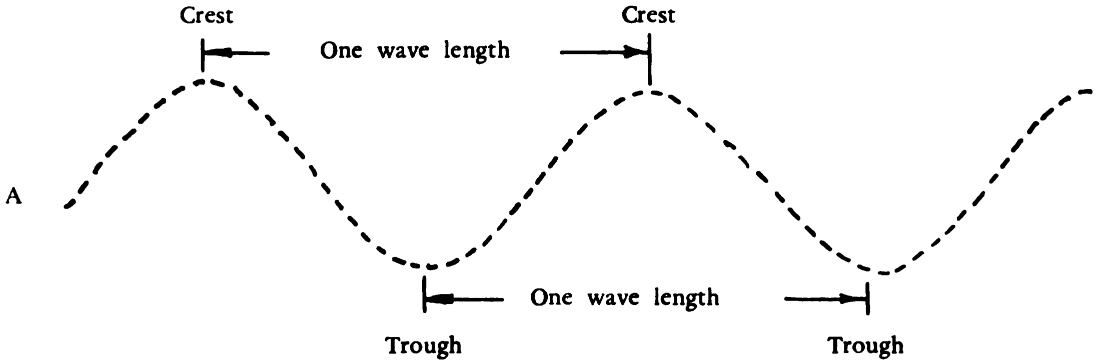
In the total field of radiation, the portion of greatest interest to us in the field of X-radiation hygiene is the ionizing radiation in the electromagnetic spectrum. The electromagnetic spectrum shown in Figure II–5 gives many of the radiations belonging to this group and their respective wave lengths, energies and frequencies. Of special interest to you in X-ray technology are the two radiations that have been named gamma rays and X rays.



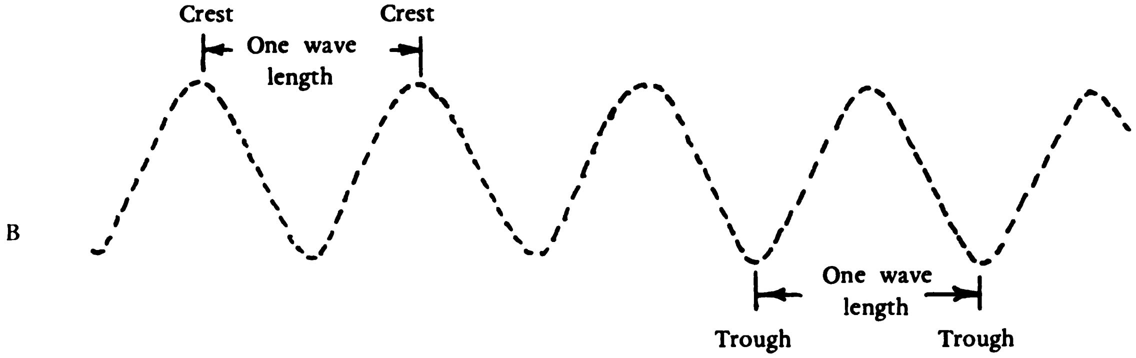
Angstrom unit: Unit of length equal to 10^{-10} meters.
Electron volt: The amount of energy acquired by an electron accelerated through a potential difference of one volt.

Figure II—5. The electromagnetic spectrum.

All electromagnetic radiation, which includes X rays, travels at the speed of 3×10^{10} centimeters per second in a vacuum. This is nearly equal to 186,000 miles per second. In Figure II–6, electromagnetic radiation is represented as having a wave form. The distance between successive crests or troughs is the wavelength and is usually represented in equations as the Greek letter lambda (λ). The number of waves passing a given point in one second is called the frequency of the radiation. In the following example, the letter f is used to represent frequency.



Longer wave length = lower frequency = lower energy



Shorter wave length = higher frequency = higher energy

Figure II–6. Diagram of the wave motion of an X ray showing crest, trough and wave length. The wave length (crest to crest or trough to trough) is greater in "A" than in "B". Thus "A" has less frequency, less energy and less ability to penetrate matter than "B".

The product of the frequency (f) and the wavelength is equal to the speed (velocity) of the radiation which is represented by the letter c. Thus for different values of lambda (λ) a corresponding but opposite change in the frequency (f) must occur so that the speed (c) of the electromagnetic radiation will remain constant. Variation in wave length and frequency is also characterized by the energy component of the radiation. See Example I.

Example I

Given λ = wave length in centimeters

f = frequency in cycles per second

c = speed of electromagnetic radiation = 3×10^{10} cm/sec

$c = f\lambda$

How does the wave length change as frequency changes?

If we let c be equal to 12 instead of 3×10^{10} cm/sec, then $12 = f\lambda$

Assume $f = 1$ then $\lambda = 12$
Assume $f = 2$ then $\lambda = 6$
Assume $f = 3$ then $\lambda = 4$
Assume $f = 4$ then $\lambda = 3$
Assume $f = 6$ then $\lambda = 2$
Assume $f = 12$ then $\lambda = 1$

Note that the frequency varies inversely with the wave length; in other words, as one goes up in numerical value, the other goes down.

The approximate frequencies, wave lengths and energy of some components of white light, ultra violet and X radiation are shown in Figure II–7.

Name of radiation	Energy in electron volts	Frequency in cycles/sec	Wave length		Speed in cm/sec
			Angstrom	cm	
Red	1.90	4.62×10^{14}	6500	6.5×10^{-5}	3×10^{10}
Orange	2.03	4.92×10^{14}	6100	6.1×10^{-5}	3×10^{10}
Yellow	2.18	5.26×10^{14}	5700	5.7×10^{-5}	3×10^{10}
Green	2.38	5.77×10^{14}	5200	5.2×10^{-5}	3×10^{10}
Blue	2.76	6.67×10^{14}	4500	4.5×10^{-5}	3×10^{10}
Violet	3.10	7.50×10^{14}	4000	4.0×10^{-5}	3×10^{10}
Ultra violet	162	3.95×10^{16}	76	7.6×10^{-7}	3×10^{10}
Grenz X rays	12,300	3.00×10^{18}	1	1.0×10^{-8}	3×10^{10}
X rays	123,000	3.00×10^{19}	0.1	1.0×10^{-9}	3×10^{10}

Figure II-7. Visible, ultra violet and X radiation.

X radiation has a greater frequency and shorter wave length, and consequently greater energy, than does the visible portion of the spectrum. It is the greater energy of the X radiation which enables it to penetrate matter to a greater extent than does visible light. The penetration, accompanied by ionization, results in the detrimental changes to living tissue through which the radiation passes.

D. The Electron Volt

A convenient unit of energy and the one most used in this manual is the electron volt or one of its multiples. An electron volt is defined as the amount of energy acquired by an electron when it is accelerated in an electric field which is produced by a potential difference of one volt. The electron volt is illustrated in Figure II–8. The multiples of the electron volt that are most often used are the kilo electron volt, abbreviated keV, and million electron volt, meV, representing thousands and millions of electron volts respectively.

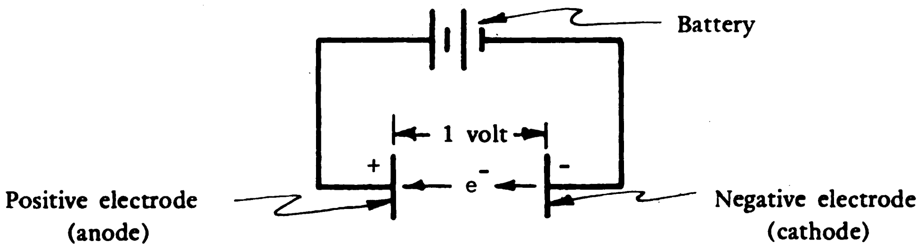


Figure II–8. The electron volt.

Unlike electrical charges attract each other and like charges repel each other. The negative electrode of a battery has excess electrons on it. These negative charges are repelling each other and are being attracted to the positive electrode.

In using an X-ray generator to produce a dental radiograph, the operating voltage is between 50 and 90 thousand volts or 50–90 kilovolts (kV). If you were using a voltage in the X-ray generator of 65,000 volts (65 kV), each electron that moves across this difference of potential from the negative electrode (cathode) to the positive electrode (anode) can gain 65,000 electron volts, or 65,000 eV, or 65 keV, or 65 kilo electron volts of energy.

E. Production of X rays

In generating portions of the electromagnetic spectrum it is possible to use the principle employed in a neon sign. Since the electrons in any atom are arranged in energy levels about the nucleus with the energy being least in the level closest to the nucleus and greatest in the level farthest removed from the nucleus, then, if an electron falls from an outer level to an inner level, it will release the amount of energy equal to the difference in the energy content it had in the level from which it moved, and the energy content of the level to which it moved.

When this takes place, the resulting energy is generally emitted as electromagnetic radiation. If this energy is in the range of 2–3 electron volts, it will be in the visible portion of the electromagnetic spectrum and may be seen. See Figure II–7.

An electrical discharge can be created when a gas, such as neon, is sealed inside a tube together with two electrodes, one of which will be positive (anode) while the other will be negative (cathode). When these two electrodes are connected to a source of electric power, a difference of electrical potential (or voltage) occurs. If this difference of potential is sufficient, it moves electrons from one electrode (the negative cathode) to the other (the positive anode) and there is an electrical discharge. The gas confined in the tube is in the path of the moving electrons and therefore is bombarded by them.

During this bombardment, the electrons from the power supply dislodge electrons in the atoms of the gas in the tube. When an electron is removed from an atom in the gas, another electron moves from an outer shell into the position which was vacated. This transition releases electromagnetic radiation and is visible if the tube is filled with neon or similar gases. The actual color seen depends on the type of gas in the tube, as well as on the electron transitions in the atoms of the gas being bombarded.

If we wish to generate radiation of higher energy than the visible portion of the electromagnetic spectrum, it can be done by a similar arrangement of the tube and electrodes, except that the tube is evacuated and the anode is generally made of copper with a target area of tungsten. See Figure II–9.

In such a tube the potential required to push an electron across the gap between the electrodes is greater than it was in the case of the neon-filled tube. This, of course, will generate radiation of higher energy (shorter wave length) than was generated in the neon-filled tube. This radiation, being more energetic, is likewise more penetrating and has been given the name X radiation.

In the production of X rays in ordinary X-ray machines, only a small amount of the energy consumed goes into producing electromagnetic radiation (approximately 1 percent). The remainder is converted into heat. Consequently, the tube is constructed to disperse the heat.

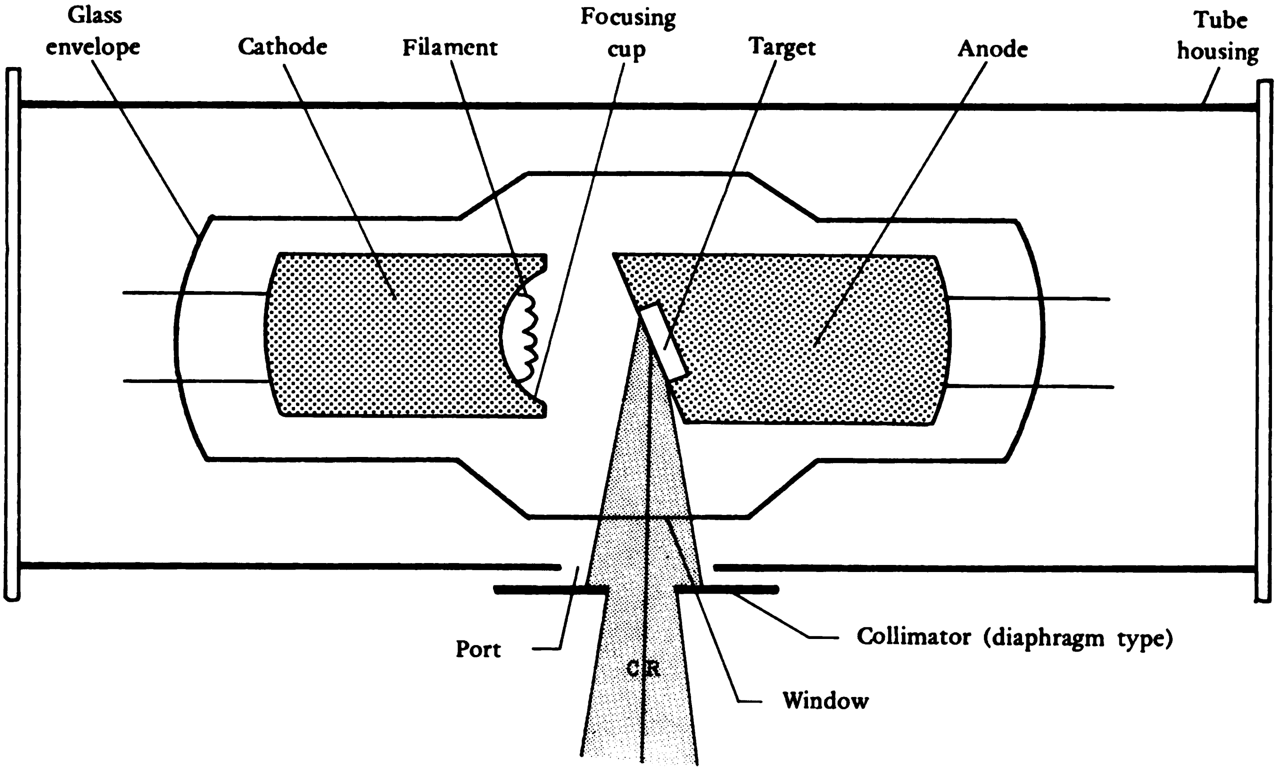


Figure II–9. The X-ray tube.

Although an electron that is accelerated radiates electromagnetic energy, in the production of X rays it is the deceleration of the electron as it hits the target that generates essentially all the usable X-ray beam. If the electron being propelled is suddenly stopped, the maximum amount of energy will be released as X radiation. The maximum amount of such energy (in eV) released will be numerically equal to the voltage across the electrodes of the tube. The energy produced in such a generator is not all produced in one collision, but is produced mostly by smaller changes in energy of the propelled electron. Consequently, the radiation produced by this generator has a variety of energies, from the largest, which is equal to the difference of potential measured as electron volts, down to a small energy near the visible spectrum, and referred to as soft X rays. (See Figure II–5). In other words, the output of the X-ray generator has a spectrum, or a distribution of energies in the composite rays produced within a certain range, which is determined by the kilovoltage used.

In order to discuss this information in a more applicable manner, it is suggested that you refer to Figure II–11, which shows the components of an X-ray tube. Please note in the figure that when the propelled electrons change energy content, radiation can come off in any direction. The figure also shows energy radiating in about one-half a sphere, or a hemisphere, and very little going beyond the anode. One reason for this is that the energy is generated on or close to the surface of the anode, which is a relatively large piece of metal and acts as a good shield or absorber for the radiation emitted in the direction of the target. Thus, very little radiation is emitted through the anode. It may also be noted that the source of electrons is a small metallic filament across the cup-shaped cathode. This filament is like the one in your electric light bulb. When it is heated to red or white heat, electrons are literally boiled out of the wire. Since the filament is close to the cathode, electrons are immediately pushed away from the cathode by virtue of like charges repelling each other. They are at the same time attracted to the anode because unlike electrical charges are attracted to each other.

The number of electrons boiled out of the filament depends upon the temperature of the filament, which in turn depends upon the amount of current flowing through the filament wire. The hotter the wire, the more electrons boiled out and consequently the more electrons pushed toward the anode and therefore available for X-ray generation. The actual number of electrons consumed in generating X radiation is proportional to the current flowing across the electrodes in the tube.

This current is generally measured in amperes or fractions of amperes, such as milliamperes (mA), or thousandths of amperes, and is regulated by the dial marked milliamperes on the X-ray generator control pannel. Dental and medical X rays have a tube current from about 10 to hundreds of mA respectively.

At the time the energy of the electron is converted into X radiation the photon, or X ray generated by this process, has the maximum energy that this photon will have. See Figure II-10, which shows that spectral shape of radiation from a tube at two kilovolt peaks. As the photon, or X ray, proceeds from the point of origin, it must go through the glass envelope, or tube. In so doing, some of the X radiation is absorbed in or by the glass envelope (Figure II—12). The portion of the X-ray spectrum which is preferentially absorbed by the glass envelope is the less energetic radiation which is spoken of as "soft" X rays.

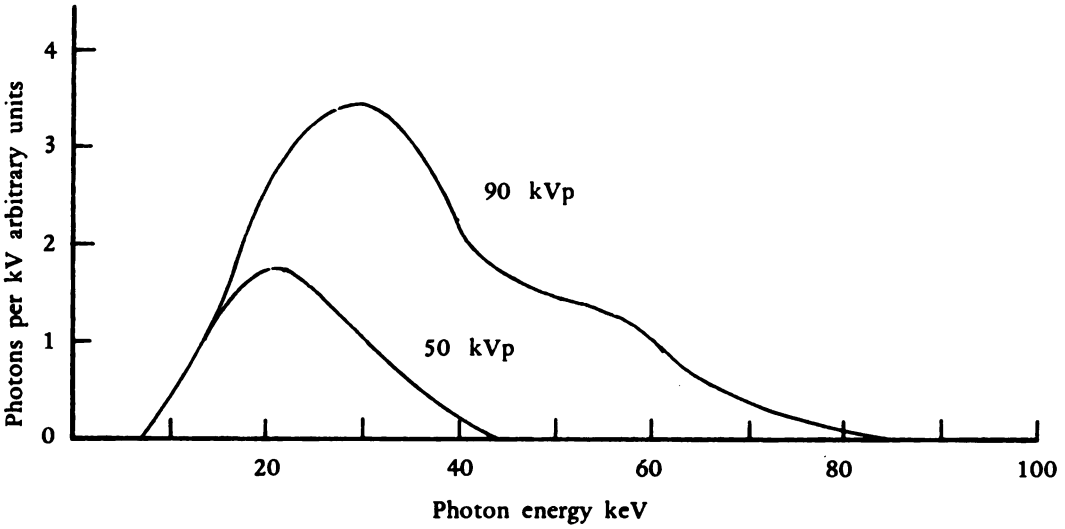


Figure II—10. Spectral shape of the radiation from a tube running at 90 kV, 150 mA and 50 kV, 69 mA, and a filter equivalent to 0.7 mm Al.

To minimize the loss of X rays passing through the glass envelope of the tube, the glass in the area of maximum X-ray generation, as illustrated in Figure II—11, is thinner than the other portions of the envelope. Figure II—12 shows additional component of the X-ray generator.

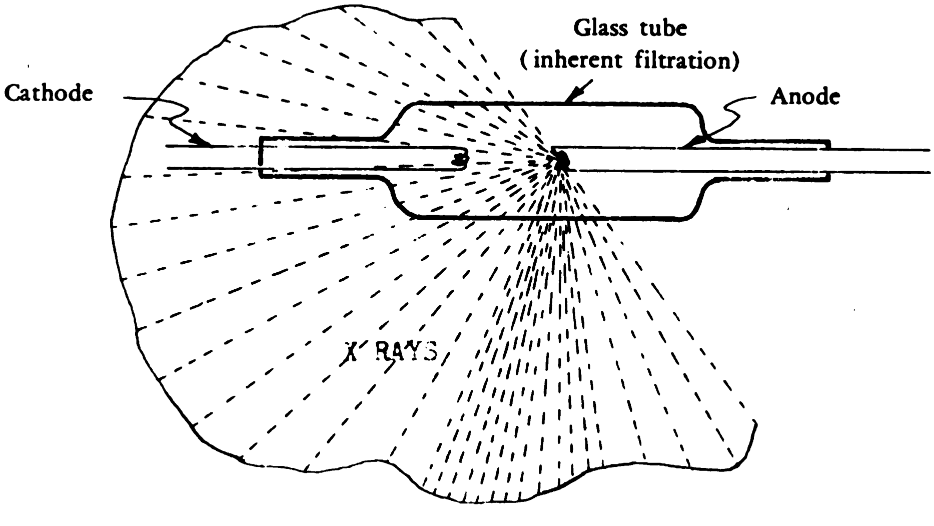


Figure II—11. X rays emanating from the tube.

The casing contains a port opposite the tube window through which the primary beam passes. The port is sealed with a material that absorbs little of the useful beam. In the illustration, the port seal is referred to as the oil exclusion cone. The remainder of the casing is designed to absorb most of the X rays emanating from the target in directions other than the primary beam.

Any radiation coming through any other part of the casing than the port is spoken of as leakage. Since the primary beam is filtered through the glass envelope, in the oil and in the casing port, it emerges with a slightly different composition of energies from those originally generated; and, as stated before, the "soft" or less energetic radiation is filtered out in greater proportion than the more energetic or "hard", X rays as illustrated in Figure II–12.

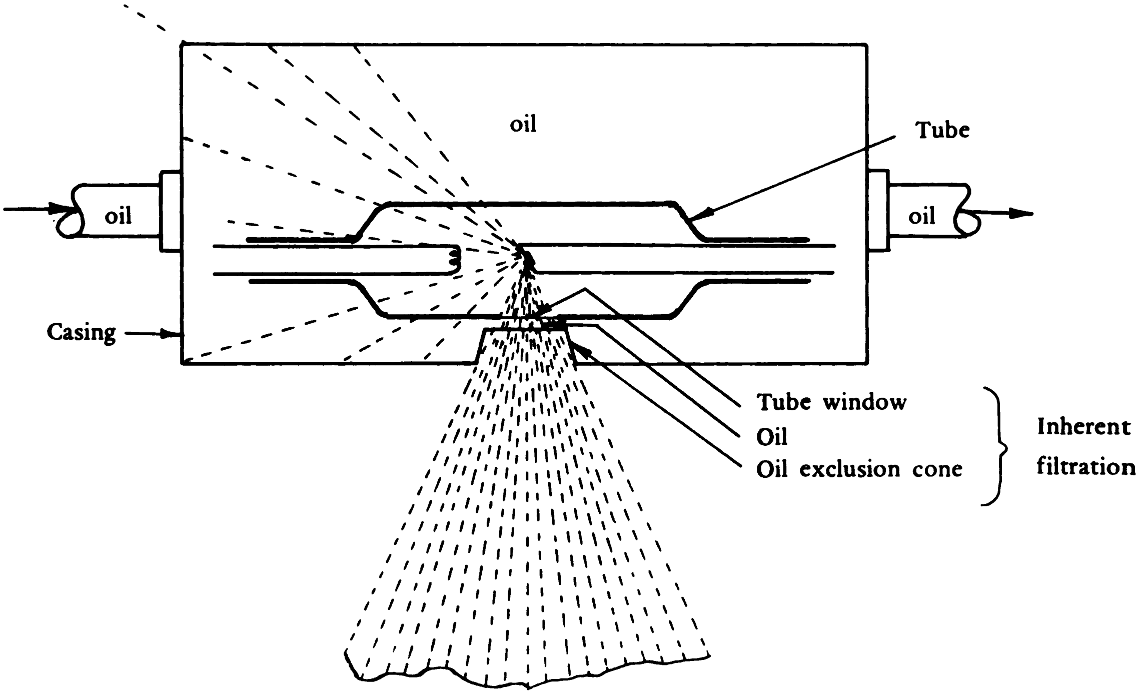


Figure II–12. Some inherent properties of an X-ray tube.

F. Filtration

X rays produced by an X-ray generator have many different energies. The weak X rays do not have sufficient energy to penetrate the most radiolucent body parts and therefore do not contribute to the image on the film. These soft X rays are absorbed by the patient and increase his radiation dose without any possible benefit, and therefore are undesirable.

When certain materials are placed in the X-ray beam, they absorb the soft unwanted X rays. This process is known as filtration. Filtration also removes a few of the energetic, penetrating X rays, but it removes many more of the weak X rays. Some filtration is accomplished by the glass wall of the tube, the insulating oil in the tubehead, and material which seals the port in the tubehead.

Such filtration is called inherent filtration. Usually this does not give enough filtration, therefore additional filtration must be added to the beam. These added aluminum filters may be sealed into the tubehead or inserted into the port. The total filtration is the sum of the inherent and the added filtration.

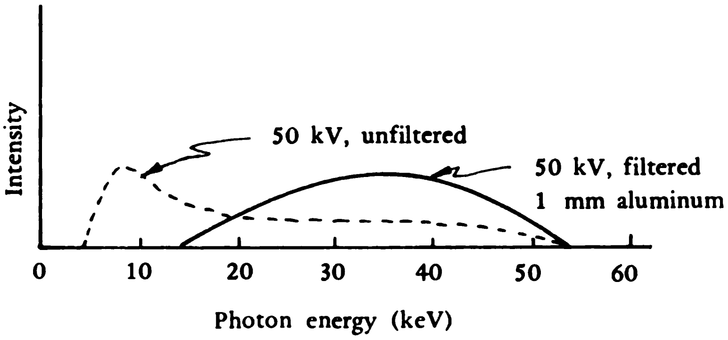


Figure II–13. The effect of filtration.

G. Collimation

The collimator, in its recommended form, is a mechanical device with an adjustable aperture for restricting and shaping the X-ray beam to the area of clinical interest. The principal reason for its use is protection of the patient and operator against unnecessary X-ray exposure. Its use also improves the quality of the radiograph. See Figures II–14 and II–15.

The collimator in its simplest form consists of a lead washer or diaphragm having an opening in the center through which the useful beam passes. It is not adjustable. If a change in beam size is desired, the old washer must be removed and a new one of the proper size inserted. This simple collimator is adequate for dental radiography.

H. Voltage

Voltage is electric potential or potential difference between the cathode and electrode expressed in volts or kilovolts. This difference in potential determines the force of attraction between the electrons and the positive anode and therefore determines the

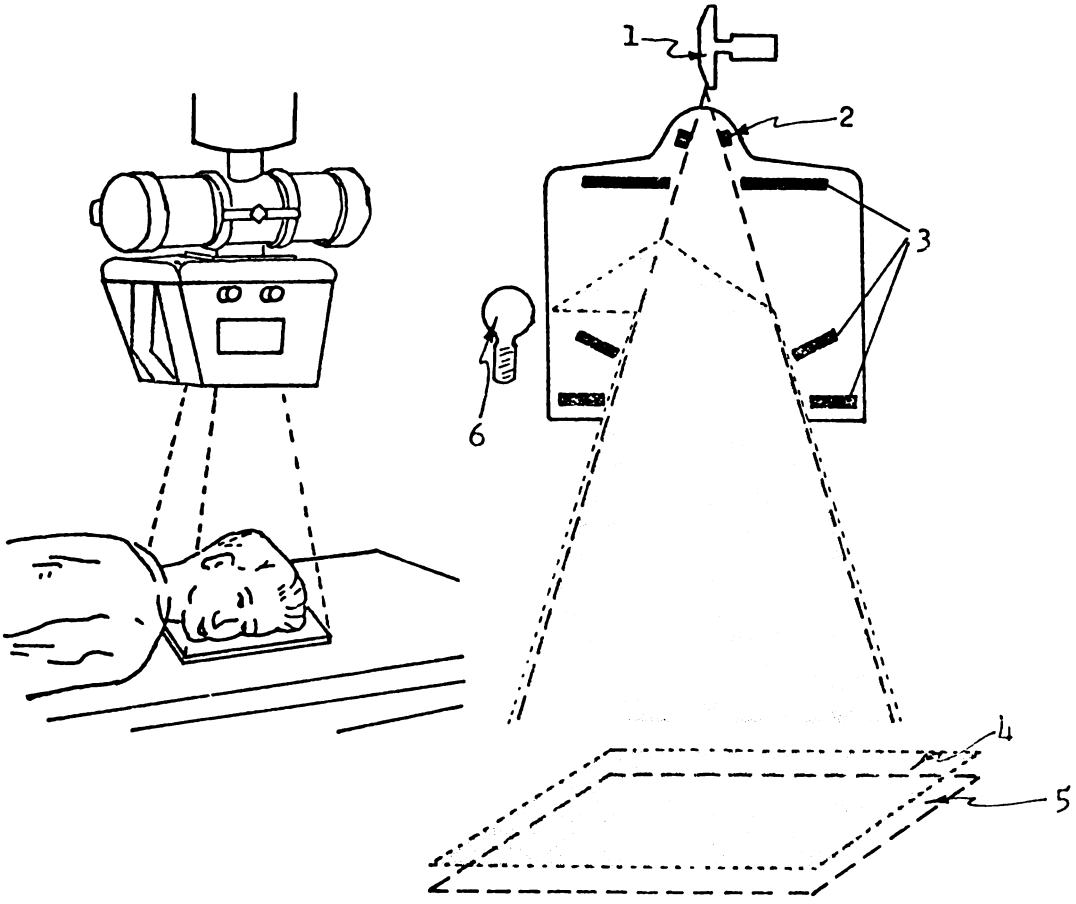


Figure II–14. Principle of the light-beam variable diaphragm. 1. Anode of X-ray tube. 2. Lead diaphragm. 3. Several lead diaphragms together forming the depth diaphragm. The light is reflected by a flat mirror in such a way that the beam of light appears to be coming from the focus. The beam of X rays than corresponds exactly to the beam of light. 4. Light area. 5. X-ray area. 6. Light source. For the sake of clarity, the light beam is shown separate from the field of radiation. (Excerpted from the book "MEDICAL X-RAY TECHNIQUE" by G. J. Van der Platts; used with the permission of MacMillan, London and Basingstoke, and with the cooperation of Charles C. Thomas, Publisher, Springfield, Illinois.)

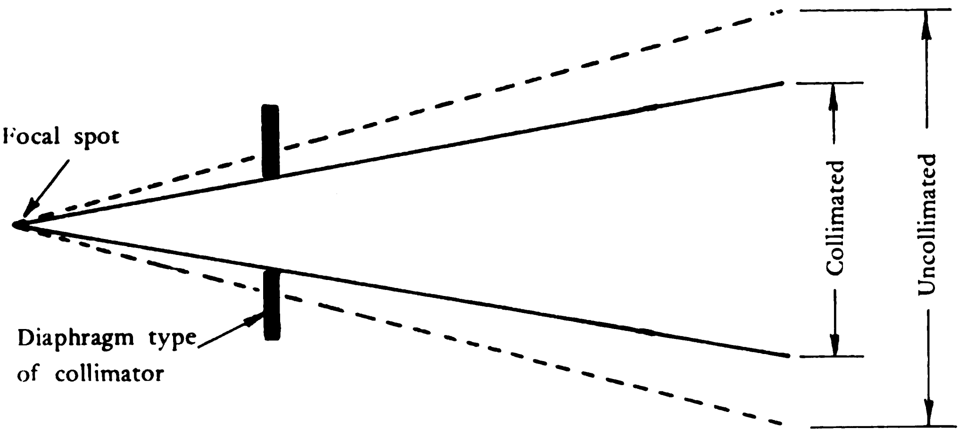


Figure II–15. Effect of collimated X-ray beam.

speed of the electrons when traveling from the cathode to the anode. The speed which the electrons have when they strike the target determines the energy of the X rays produced. The higher the voltage, the faster the electrons travel; and the greater the electron velocity, the greater the energy and penetrating ability of the X rays produced. Some machines are designed so that the kilovoltage can be varied and others are fixed at some predetermined kV value.

I. Amperage

Amperage is a measure of a current of electricity in amperes. One ampere is defined as the practical unit of electric current, being that produced in a conductor by one volt acting through a resistance of one ohm. An ampere is a rate of flow unit. The quantity of current is the ampere-second (coulomb).

Note that voltage determines the energy or penetrating ability of the X rays produced and amperage determines the quantity or number of X rays produced.

It must be pointed out that the beginner may be confused about which amperage is which for there are two important amperages. The first is the filament amperage in the filament circuit. The current in this circuit has an amperage of about 3 to 5 amperes (not milliamperes) and is responsible for heating the filament. The second is the flow of electrons from the cathode to the anode. This current is measured in milliamperes. This current flows only when the voltage differential is applied between the two electrodes and only when the anode is positive and the cathode negative. The amperage of this current may vary from 0.5 milliampere to as high as 1200 milliamperes, depending upon the type of X-ray equipment being used. It is this latter current that is referred to as milli-ampere-second output of the X-ray tube.

J. Alternating current

Alternating current (AC) is a flow of electricity in which the electrons reverse their direction again and again along a conductor. When alternating current travels back and forth in its circuit once, it has completed one cycle. The number of cycles it completes in one second is called its frequency. Each cycle consists of two alternations or impulses per unit of time. The type of alternating current used almost exclusively in the United States has a frequency of 60 cycles per second (also called hertz). Since there are 60 cycles per second in U. S. electric current and there are two alternations per cycle, then there are 120 changes in current direction per second or there are 120 impulses per second and each impulse has a duration of 1/120th second. See Figure II–16.

Alternating current is a much more suitable and versatile source of power than direct current (flows in only one direction) which is limited in the number and kinds of its application to power machinery and electronic circuits. One reason is that alternating current, voltage and amperage, may be increased and decreased readily with little loss of energy by the use of transformers. This is of primary importance in the operation of X-ray equipment.

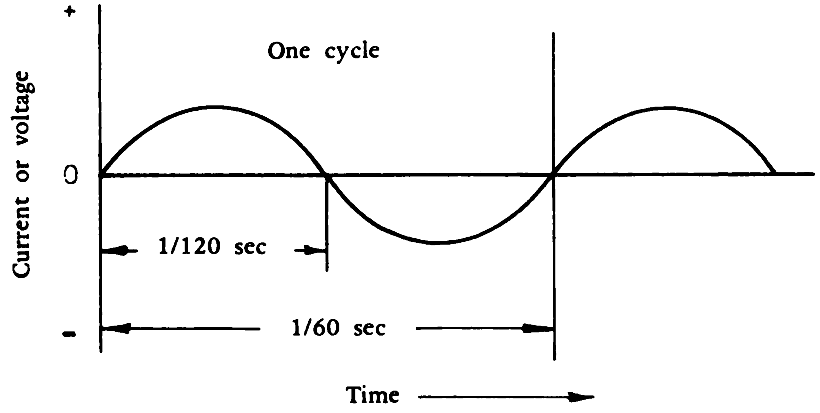


Figure II—16. Alternating current, 60 cycles per second

Without discussing how transformers work, it is sufficient to say in this manual what function they perform. With a transformer, the voltage of alternating current can be increased with a corresponding decrease in amperage and vice-versa. For example, if the voltage is increased by a factor of 10, then the amperage will be reduced by a factor of 10. When a voltage is increased, it is called a step-up transformer. When the voltage is decreased, it is a step-down transformer. In the operation of an X-ray tube, the filament circuit normally has a voltage of about 10 volts (stepped down from 120 volts) and a voltage difference across the electrodes of 5 kilovolts to as high as several hundred kilovolts (stepped up from 120 volts). Thus it is apparent that alternating current is necessary for the operation of X-ray equipment because transformers will operate only on alternating current. However, after the alternating current has been stepped up to the desired kilovoltage difference across the electrodes, the alternating current must be changed to direct current because the X-ray equipment will only produce X rays when electrons flow from the cathode to the anode. This process of changing alternating current to direct current is known as rectification.

When an X-ray tube is in operation, electrons flow from the hot filament (cathode) to the anode when the cathode is negative and the anode positive. When the reverse is true, that is, the cathode is positive and the anode is negative, there is no flow of electrons.

Refer again to Figure II—16. If the cathode is assumed to be negative when the curve is above the zero line and positive when the line is below, then it is obvious that the X-ray tube will operate only one-half of the time, that is, when the curve is above the zero line. The operation curve will then look like Figure II—17. This is called self-rectification and half-wave rectification. The alternating current has been rectified to a direct current albeit a pulsing current. An X-ray tube operated in this manner has 60 impulses per second.

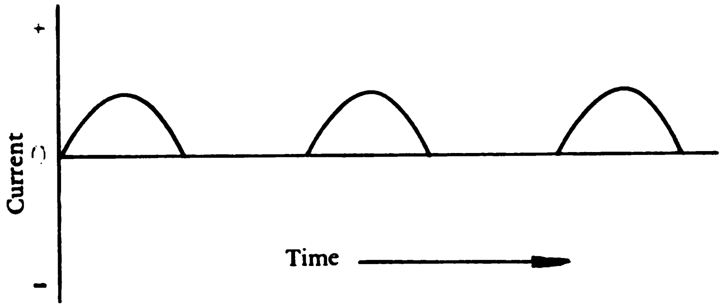


Figure II—17. Half wave rectification.

If a pair of vacuum tubes called valve tubes (they allow the electric current to flow in one direction only) are used to supply one-half wave direct current to the X-ray tube the capacity of the tube can be increased because the deleterious effect of the reverse current is divided between the two valve tubes. In this instance, the operating curve will still be as presented in Figure II—17. Full-wave rectification may be achieved with four valve tubes and is superior to half-wave rectification, as illustrated in Figure II—18, but any form of rectification is superior to self-rectification.

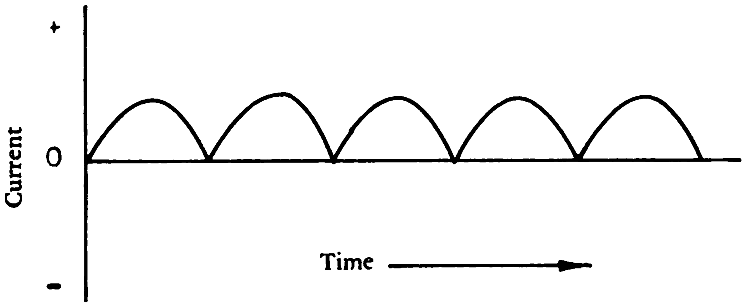


Figure II—18. Full wave rectification.

K. Effect of kilovoltage peak and milliamperage

The highest voltage to which the alternating current rises is the kilovolt peak. It is usually referred to as the kVp. This is the maximum energy which that machine will impart to an X-ray photon. The maximum energy X ray that a 65 kVp machine can generate is a 65 kilovolt X ray. The X-ray machine also produces X rays that have lesser amounts of energy down to rays which have just enough energy to escape from the tube. These low energy X rays are commonly called soft X rays or Grenz rays.

High kV X rays have a greater penetrating ability than the lower kV X rays and therefore produce a different kind of a radiograph. High kV radiographs exhibit what is known as long grey scale. Low kV X rays exhibit what is known as short scale – high contrast radiographs. The decision as to the kilovoltage to be used should be made by the doctor who must interpret the films. It is imperative that the doctor gets the type of radiograph from which he can obtain the greatest amount of information.

Milliamperage controls the number of X-ray photons that will be produced per second. For a given milliamperage, the total X-ray photons produced will depend upon the exposure time. The product of milliamperes and time is known as milliampere seconds (mAs). Within the limitations of the equipment it is generally desirable to use a high milliampere setting so that a short time setting can be used. Short time settings help to reduce retakes due to movement of the patient.

L. X-ray timer switches

The timer circuit consists essentially of a timing device that can be varied. This timing device activates a contactor which allows the high voltage to be supplied to the X-ray tube. The timer itself is a modification of a push button switch with a timing mechanism which automatically cuts off the current after a preset time.

There are four main types of timers in general use today. These are the hand or mechanical timer, the synchronous timer, the impulse timer, and the electronic timer. There is also a photoelectric timer which is not widely used and will not be described here.

The mechanical timer has a spring wound motor which is allowed to run at a constant speed, the timing dependent upon how far the dial is initially set. It has a theoretical minimum time of 1/8 second. It is not advisable, however, to use such timers for intervals less than 3/8 seconds because of its inaccuracy at shorter intervals.

The synchronous timer consists of a small synchronous motor, the revolutions of which are counted and used as the timing factor. These timers can usually be set for time intervals from 1/20 second to about 20 seconds, the exact time depending upon the manufacturer's design, as is true of all types of timers.

The impulse timer may operate at time intervals of 1/120 second to about 1/5 second. Because the maximum timing exposure is approximately 1/5 of a second, a synchronous timer is generally installed along with the impulse timer to provide for the longer exposures. The impulse timer is much more accurate than the synchronous timer since it starts and stops the current at the no current point of the alternating current cycle.

During the past few years the electronic timer has become widely used. It uses vacuum tubes to count the alternating current pulsations. The timer covers the range from 1/120 second to 20 seconds more accurately than any of the above timers.

Timer switches must be of the deadman type. Such switches will terminate the exposure if the switch is released during the procedure. It is therefore necessary to maintain firm pressure on such a switch until the timer terminates the exposure. On many machines, closing the timer switch preheats the filament and the machine does not operate until the filament reaches its operating temperature. Observing the milliammeter indicator will show if X rays are being generated, because the ammeter operates only when electrons are flowing from the cathode to the anode, the period when X rays are being generated.

M. Inverse Square Law

As one moves further away from an X-ray source, the less radiation he receives because the X-ray beam diverges as it moves away from its source. See Figure II–19. The radiation intensity decreases as the distance increases according to the inverse square law. This law is, "At points distant from a common source of X radiation, the intensities of radiation at these points vary inversely as the squares of their respective distances from the X-ray source." This can be expressed as a simple mathematical relationship.

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2} \quad \text{or} \quad I_1 (D_1)^2 = I_2 (D_2)^2$$

Where: I_1 = intensity at distance D_1

I_2 = intensity at distance D_2

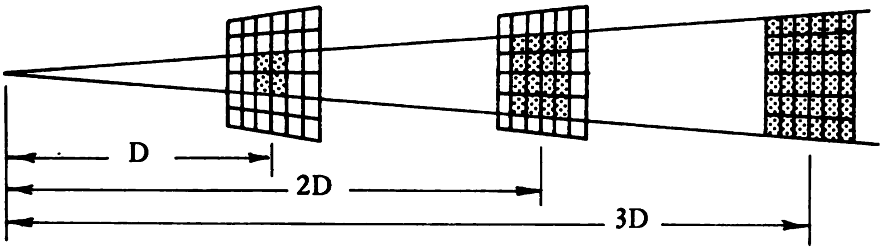


Figure II–19. The inverse square law.

As a practical example for illustrating the Inverse Square Law, assume conditions that would be found in a dental office where 8 and 16 inch aiming cylindrical cones are used. If the intensity of radiation at the end of the 8 inch cone is one unit, then what is the intensity at the end of the 16 inch cone?

Given	Calculation
I_1 = 1 unit of radiation at D	Using $I_2 (D_2)^2 = I_1 (D_1)^2$
I_2 = unknown unit of radiation at 2D	$I_2 (16)^2 = 1(8)^2$
D_1 = 8 inches (D)	$I_2 = \frac{8^2}{16^2} = \frac{64}{256} = \frac{1}{4} =$
D_2 = 16 inches	$I_2 = \frac{1}{4}$ unit of radiation

It is easy to remember that if the distance from an X-ray source is twice as great (2 squared is equal to 4), the radiation is reduced to 1/4 of the intensity at the original distance; if the distance from the source is tripled (3 x 3 = 9), the intensity is reduced to 1/9; if the distance is 4 times then the intensity is 1/16, etc. This effect is illustrated in the following table which assumes that at a distance of one inch the exposure level is 100 roentgens.

The Inverse Square Law

Tube to target distances inches	Intensity in R/sec.	Fraction of radiation intensity
1	100.0	1
2	25.0	1/4
3	11.1	1/9
4	6.2	1/16
5	4.0	1/25
8	1.5	1/64

N. Interaction of radiation with matter

Electromagnetic radiation interacts with matter in a number of ways. Nearly everyone is familiar with some of these interactions, for example: light can bleach certain dyes in clothing; light waves affect the film in our cameras, making photography possible; ultraviolet rays cause the production of Vitamin D in our skin; ultraviolet rays can also tan or burn skin.

All radiation possesses energy. Electromagnetic radiation is the process of transferring its energy to atoms of the medium through which the radiation is passing. To say that radiation interacts with matter is to say that it is either scattered or absorbed. The mechanisms of the absorption of radiation are of fundamental interest to radiologists primarily because of the following reasons:

1. Absorption in body tissue may result in physiological injury;
2. Absorption is the principle on which detection of ionizing radiation is based, and
3. The degree of absorption or type of interaction is a primary factor in determining shielding requirements (if necessary).

The transfer of energy from an X-ray beam to atoms of the absorbing material occurs essentially by one process and that process is ionization. However, the ionization process by X rays of moderate energies (less than 1.02 million electron volts) occurs by two mechanisms which are 1) the photoelectric effect and 2) the Compton effect.

The photoelectric effect is a complete one-collision loss of energy. The X-ray photon (see glossary for definition) imparts all its energy to an electron of some atom and ceases to exist. The energy is imparted to the electron in the form of kinetic energy of motion. This greatly increased kinetic energy of the electron overcomes the attractive force of the nucleus and causes the electron to fly from its orbit with high velocity. Thus an ion pair results. The high energy electron now called a photoelectron has sufficient energy to knock other electrons from their atoms, thus producing secondary ionization until all of its energy is lost.

The Compton effect provides a means of partial energy loss for the incoming X ray. Again, the X-ray photon reacts with an electron of some atom. In this case, however, only a part of the energy is transferred to the electron. The X-ray photon staggers on with less energy and probably in a new direction. This is called scattering. The high velocity electron, now referred to as a Compton electron, causes secondary ionization in the same manner as the photoelectron, and the less energetic X-ray photon continues on until it loses more energy in another Compton interaction or disappears completely by the photoelectric effect. The unfortunate aspect of Compton interactions is that the direction of flight of the less energetic X-ray photon is equally distributed in all directions, so that scattered radiation may appear around corners and behind shadow type shields.

O. Units of radiation measurement

The harmful consequences of ionizing radiation to living tissue are due to the energy absorbed (dose) of the cells of the tissues. The mechanism by which such damage occurs appears to be related to the ionizing ability of the radiation. The amount of ionization that a quantity of radiation produces provides the basis by which ionizing radiation is measured. Not all radiation in the electromagnetic spectrum causes ionization. The basic unit of measurement for gamma and X radiation only is the roentgen (R). The rad and rem are units of measuring absorbed dose from any radiation. The three units are essentially equal in X-ray exposures.

There are, however, differences in concept in the three units. The roentgen is a measure of radiation, based on the amount of ionization produced in one cubic centimeter of air under standard conditions of temperature and pressure. One roentgen of exposure will produce about two billion ion pairs. The roentgen does not indicate the area of exposure or the total energy absorbed by the body.

The unit of absorbed dose is the rad (Radiation Absorbed Dose) which is a measure of the energy absorbed per gram of material. The rad as a unit of radiation applies to any kind of ionizing radiation, while the roentgen applies only to X and gamma rays. A rad describes the amount of energy absorbed by one gram of matter.

The rem (Roentgen Equivalent Man) is a unit used to equate the effect of different kinds of ionizing radiation. The rem is often called the unit of biological dose. When dealing with X rays, the roentgen, the rem, and the rad are all used.

One roentgen of exposure in air will produce about one rad of absorbed dose in soft tissue which is equivalent to one rem. Since the dental laboratory radiographer deals only with X rays he can use this relation of units:

1 roentgen (1 R) = 1 rad = 1 rem.

It is important to remember that, in comparing different radiographic procedures, we must consider not only "exposure" and "absorbed dose" but also area and volume of tissue involved and the energy of the radiation.

III. RADIATION PROTECTION

Exposure of the human body to X radiation is biologically undesirable. In striving for good radiological health practices in dentistry, our goal is to reduce radiation exposure to the patient and the operator to the minimum, consistent with diagnostic requirements. Several responsible organizations have developed recommendations designed to help attain this goal. In some states these recommendations have been incorporated into their radiation protection laws and thus are compulsory. The principal groups which have published recommendations for dental use are the National Council on Radiation Protection and Measurements (NCRP) and the American Dental Association (ADA).

A. Methods for reducing exposure

1. Filtration

The purpose of filtration is to absorb soft or low energy X rays which do not have sufficient penetrating power to reach the film and thus do not contribute to the radiographic image. Soft X rays are absorbed by the patient and contribute unnecessary radiation exposure. The total filtration is composed of the inherent filtration built into the X-ray generator, plus any added filtration. If additional filtration is required it is accomplished by placing thin disks of aluminum in the X-ray beam. These disks are usually 0.5 mm thick and the added filtration is expressed in millimeters of aluminum.

2. Collimation

Collimation is the restriction of the primary beam to a size which will expose only the area of diagnostic interest. Limiting the beam to the required 7 cm (2.75 inches) diameter* is one of the most effective ways of reducing radiation exposure. Restricting the beam to the recommended size markedly reduces exposure to the thyroid gland and lens of the eye, two tissues which are especially sensitive to radiation.

Collimation is usually accomplished through the use of a lead washer diaphragm or beam restricter. An additional benefit from proper collimation of X-ray beams is the improved definition of the radiograph, accomplished by reducing the scatter radiation from needlessly irradiated tissue. This scattered radiation fogs the film and reduces the sharpness of the image.

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* California Radiation Control Regulations, Title 17, California Administrative Code, Chapter 5, subchapter 4, Section 30311(a)(2), September 1973. A copy of the regulations may be obtained from the California Department of Health, Radiologic Health Section, 744 P street, Sacramento, CA 95814

3. Kilovoltage

The use of high kilovoltage techniques has been advocated as a means for reducing the patient's exposure. The use of higher kilovoltages will allow a reduction in facial exposure. However, the X rays generated by using high kilovoltages are more penetrating and increase the dose to the deeper structures. It now appears that the shorter exposure times are offset by the increased penetrating ability and the dose to the patient is approximately the same for high kilovoltage techniques as it is for low kilovoltage techniques.

The use of the higher kilovoltages is not considered as important in radiation protection as it formerly was. It should be remembered, however, that because of its greater penetrating ability, the use of higher kilovoltages produces a different kind of radiograph, i.e., a radiograph characterized by long grey scale. The decision to use high or low kilovoltage radiography is a professional choice and should be based upon diagnostic preference. The diagnostician should use that kilovoltage which produces the film that he feels he can best interpret.

4. Shielding

Shielding refers to the means used to stop radiation or to prevent exposure to it. Usually when we think about shielding we immediately think of heavy lead protective barriers; however, the use of shielding includes not only the use of such barriers, but also the utilization of both distance and the existing structural materials in the dental office.

a. The sources of radiation exposure in the dental office are the primary beam and scatter radiation. One should never stand or have any part of the operator's body in the primary beam. The principal sources of scatter radiation are the materials, such as a pointed plastic cone (if one is used) and the patient's face, through which radiation passes before it hits the film. We cannot eliminate the patient's face, but a pointed plastic cone causes unnecessary scatter radiation and should be replaced by an open end aiming cylinder.

b. Scattered X rays obey the Inverse Square Law just as other X rays do; therefore one of the most effective ways to protect ourselves from scatter radiation is to stand as far away from the source as practical. It is recommended that all dental X-ray machines have cords sufficiently long so that the operator can stand at least six feet away from the tube head during an exposure. The farther away the better! As a general rule the safest place to stand is in the area from 45 to 90 degrees out of the primary beam, behind the bulkiest part of the patient's head. (See Figures III–1 and III–2.) The quantity of matter (patient's head) is sufficient to absorb most of the primary beam and a great deal of the scatter radiation.

If it is not possible to stand the recommended distance from the X-ray source because of the configuration of the office, it may be necessary to use some type of barrier or shielding. The existing structural components of the office will often provide adequate shielding if they are used. For example, it may be possible to step behind a wall or out of the doorway during the time of exposure. The Radiologic Health Section of the State Department of Health will inspect registered X-ray equipment and survey a dental radiographic laboratory to help locate the safest place to stand during radiographing.

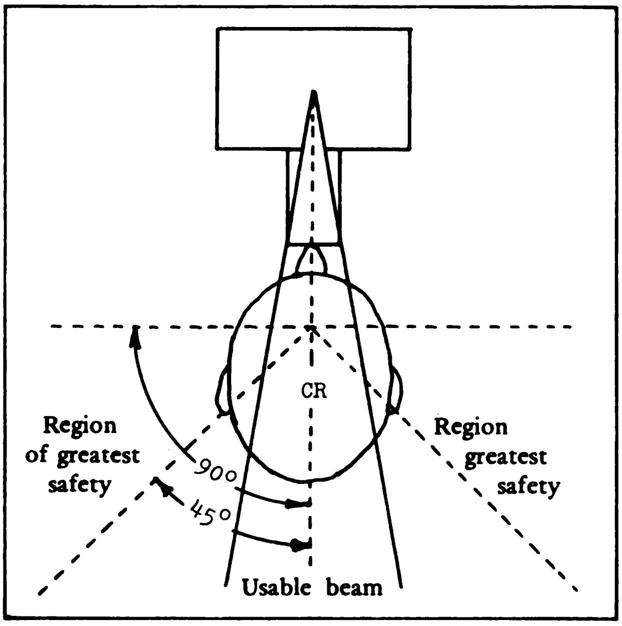


Figure III–1. Diagram illustrating the two positions of greatest safety during the projection of the central incisor region. They are located on each side of the patient's head at an angle of 45 to 90 degrees to the central ray.

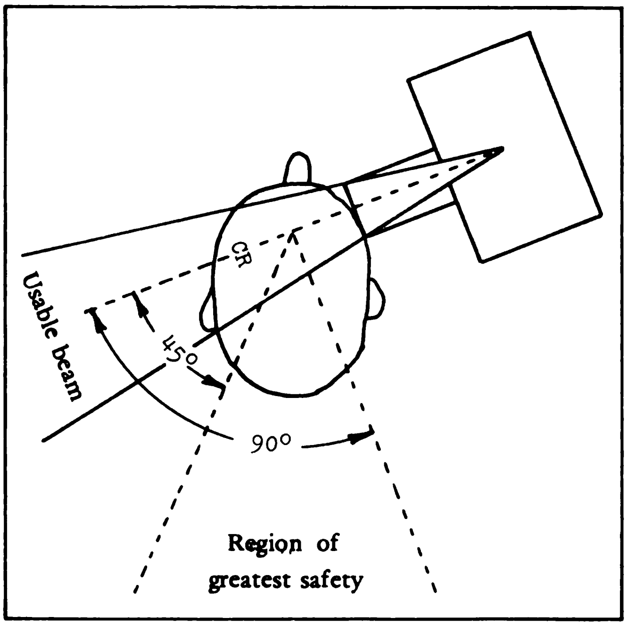


Figure III–2. Diagram illustrating the position of greatest safety for all projections except for the central incisors. It is located 45 to 90 degrees to the central ray, but the operator must stand behind the patient's head.

c. According to Section 30311(c)(6) of the California Radiation Control Regulations, each patient undergoing dental radiography shall be draped with a protective apron of not less than 0.25 millimeter lead equivalent to cover the gonadal area.

It is extremely important to use the leaded apron on young women in their reproductive ages because the most critical time for radiation exposure to the fetus is during the first three months of a pregnancy. During this period most women do not know they are pregnant. During these very early stages in the development of the fetus, the single fertilized egg cell (ovum) divides into two cells, then four, then eight, etc. A very small amount of damage at these very early stages of development could have a profound effect on the development of the entire organism.

If you are also observing all the other recommended radiation protection practices — appropriate shielding, collimation, filtration, fast film and complete development — the possibility of damage is extremely remote. However, to repeat once again, the use of a lead apron must *never* be omitted. Its use protects you from criticism and assures your patients that you are doing everything possible for their protection.

B. The use of fast film and complete development

One of the most effective means for reducing radiation exposure is the use of fast film. The radiation dose a patient receives is the product of X-ray intensity and time. Fast film reduces the exposure time necessary. However, because of its greater sensitivity, the use of fast film presents problems in both exposure and processing. It is possible to get as good a radiograph with fast film as with slow film, but to do it is essential that the film being used is correctly exposed and correctly processed.

1. Dental radiographic film

Dental radiographic films consist of a thin base, coated on both sides with a photosensitive emulsion. The emulsion is a gelatin compound containing fine grains of silver salts, usually silver bromide. When the film is exposed to radiation, a latent image is formed. During the chemical developing process, the exposed grains are reduced by the developer to small spongy particles of black metallic silver which form the radiographic image. After the latent image has been developed, fixing agents are used to dissolve the unexposed silver salts which have not been affected by the developer. Only the spongy particles of black metallic silver remain, which form the image. Chemicals are added to the fixer to harden the gelatin and to improve its keeping qualities.

Optical film density is the amount of darkening of the film caused by exposure to radiation. Contrast is the difference in density between two adjacent areas in the film. Contrast is determined by the nature of the subject radiographed and the characteristics of the film used. The relative speed of a film is determined by the amount of radiation required to produce a certain, specified density.

Fog is unwanted film darkening, and has the effect of reducing contrast. There are two types of fog; one is chemical fog, which is the development of unexposed grains of silver halide salts, due to faulty processing. The other kind is exposure fog, which is caused by exposure of the film to visible light or other electromagnetic radiation.

Dental radiographic films are supplied in assorted speeds and sizes. Film speeds are determined by the amount of radiation necessary to produce a given density. Standard Film Speed Classifications have been developed by the American National Standards Institute (ANSI) ranging from speed group A through speed group F, with A being the slowest and speed increasing as we progress through the alphabet. There are no films offered for sale in speed group A, which is the slowest speed, nor are there any speed group E and F films available at this time. At the present time we have available films in speed groups B, C, and D.

The use of the fastest film available (film in speed group D) is recommended. Speed group B is referred to as slow film, speed group C as intermediate, and speed group D is referred to as fast film. The speed categories are so arranged that to change from speed B to a speed C could be accomplished by reducing the exposure time by one-half; to make the transition from speed C to speed D would again require reducing the exposure time by one-half. Thus we can see that speed D films are roughly four times as fast as speed B film, and therefore would require only a quarter of the time to expose to the same optical density.

2. Exposure time determination

In using high speed film it is extrememly important to determine the correct exposure time. Within reasonable time limits, a correctly exposed film is very difficult to overdevelop. Once the proper exposure has been determined, development time is not nearly as critical as it is when the film is overexposed and underdeveloped. Overexposure and underdevelopment are all too common in dental practice and result in inferior radiographs. Overexposed, underdeveloped films lose contrast and do not exhibit the maximum information required by the dentist for diagnosis.

There are several ways to determine whether or not the exposure time is correct. If you have a late model X-ray machine with an accurate electronic timer the principal problem is to determine the correct exposure time. If you have an older X-ray machine with a mechanical timer, the problem is more complicated because older mechanical timers are simply not accurate nor consistent at time intervals of less than one second. There is a quick test to determine whether or not the exposure time being used is correct. This can be accomplished by either taking an extra film during a radiographic procedure or by using one of the double-film packs which are available. Take the extra film and process it in clean, fresh solutions for twice the recommended development time. If the film is still readable you can be assured that your exposure time is very close to correct. If the film is too dark to be read, you are overexposing.

In the event you have an older mechanical timer there are three ways in which this equipment can be adapted to use modern high speed film.

a. Install an electronic timer converter.

b. Change to a long cone technique. The increased distance requires a longer exposure (as covered by the Inverse Square Law) that will be in time range at which the mechanical timer is accurate.

c. Reduce the milliamperage. The amount of radiation necessary to expose a film is a constant determined by the product of the milliamperage and the time in seconds. It is referred to as milliampere seconds (mAs). By reducing the milliamperage it is possible to increase the time to the range where the timer is sufficiently accurate. It may be necessary to call a service man to adjust the milliamperage if this technique is used.

   There are several ways to establish the correct exposure time. One way is to start with the recommended exposure time supplied by the manufacturer on the film package and adjust it accordingly on a trial and error basis (test by developing for twice the recommended time as previously described). Another method has been developed and published by Dr. A. H. Wuehrmann in his booklet, "Radiation Protection and Dentistry", (See Appendix B.)

3. Complete development techniques

Fast film is not only more sensitive to X rays but also more sensitive to visible light. A darkroom which has been satisfactory for use with slow film may not necessarily be adequate for processing fast film.

When we refer to complete development techniques, we usually mean developing for five minutes at 70 degrees Fahrenheit (F). For routine processing a time-temperature technique should be used. The development time should be at least as long as the manufacturer recommends and frequently we can increase the development time from 24 to 40 percent without adverse effects. However, as an aid to the radiographer in determining development time, the following time-temperature chart will be useful:

Temperature (degrees F)	Minutes in developer
74	3
72	4
70	5
68	6
66	7

After developing, the film should be transferred to the wash tank for approximately 20 seconds to rinse off the developing solution and avoid contaminating the fixer. Films should be fixed for at least 10 minutes in order to remove completely the unexposed silver halide grains and to harden the emulsion so that the film can remain in good condition. Following fixation, the radiograph should be washed for 20 minutes and then thoroughly dried.

Because of the great sensitivity of fast films, an adequate darkroom and proper safelights are imperative. To check light leaks, stay in the darkroom for at least five minutes to allow your eyes to dark adapt and then examine the area around the door, etc., for light leaks. The correct safelight should be positioned four feet from the working surface and should have a 7.5 watt bulb. The recommended safelight is a No. 6B, formerly identified as a Wratten 6B filter. Several manufacturers now offer safelight-film combinations which allow a greater intensity of light in the darkroom (Morlite and Pluslight). It is important to note, however, that if other films, such as medical type films, are to be processed, it is still necessary to have a 6B filter in order to prevent fogging the film. In the handling of films it is important to maintain cleanliness and the film should be handled gently to avoid scratches, fingerprints and chemical contamination. The processing tanks should be kept covered when not in use and solutions should be changed at least every three to four weeks. In the case of heavy workloads it may be necessary to use replenishers or to change the solutions more frequently. In the average radiographic laboratory, deterioration of the solutions from exposure to air depletes them more rapidly than the workload.

C. Personnel monitoring

If you are concerned about the amount of radiation to which you are being exposed, there are several personnel monitoring systems or devices which can measure your exposure. The film badge is the most economical and the most widely used. A film badge service company can supply a film badge which you wear above the waist during the work day. Each month you receive a new film to be placed in the badge and return the old film to the company. The company processes the film, determines the amount of exposure, and sends a written report of the results. The report will state the amount of radiation you received and constitutes a permanent record of your exposure.

It is suggested that the film badge service be subscribed to for at least one quarter of a year. If the results indicate that you are not receiving significant amounts of exposure, it could then be discontinued. From time to time you should repeat the film badge service to detect if there is any sudden increase. A sudden large increase would indicate that you have changed your work habits or are becoming careless. A dental film with a paper clip or a penny attached to it is not an acceptable substitute for a good film badge service.

Another method available to check on your exposure is the use of pocket dosimeters. These devices are considerably more expensive but can be read immediately and you can thereby determine your radiation exposure for any given time interval.

D. Mechanism of biological injury

There are two generally accepted theories of radiation injury to biological systems.

1. Direct hit or target theory

The direct theory proposes that some of the damage or injury that occurs is the result of a direct hit on an atom by an X-ray photon. Certain constituents of the cell are composed of very large, complicated chains of atoms which form huge chemical molecules, called macromolecules. It is believed that a direct hit on an atom in such a molecule will sometimes inactivate or impair the function of the entire molecule, which may, in turn, affect other cell constituents.

2. Indirect action or poison water theory

The indirect theory states the effects of radiation are due to the ability of radiation to ionize water. Water is the most abundant chemical in the human body. About 80 percent of the body is water. When water is ionized it is broken into radicals which may recombine to form water again, or may combine with other radicals to form new chemicals. It is believed that many of these compounds are toxic to the cell and can affect the entire cell function.

An example of this is the dissociation of water into hydrogen (H^+) and hydroxyl (^-OH) radicals. If two hydroxyl radicals combine, they form H_2O_2 which we all know as hydrogen peroxide. Inside a cell, such a strong chemical agent would have a pronounced effect. The indirect theory proposes that a number of such chemical poisons are formed to produce the effects observed following radiation exposure.

Other theories have been proposed about how X radiation does its intracellular damage. There is general agreement that long-term, low chronic doses of radiation affect organisms principally by altering the cells' ability to reproduce normally.

E. Cellular effects

The cell is the building block of the body. Although there are many kinds of cells (for example, muscle cells, nerve cells, etc.) that make up the body's different tissues, all cells have certain things in common. Cells all possess a cell wall, cytoplasm, and a nucleus. The cell wall encloses the cytoplasm. Incorporated in the cytoplasm is the nucleus which controls some of the cell's activities. It is within the cell that the primary damage by radiation is done.

Large groups of similar cells with a specialized function are called tissues, e.g., skin tissue, dental pulp tissue, bone tissue, etc. Tissues react to radiation to the same degree as their constituent cells do.

Mitosis is the means by which cells reproduce. In mitosis the cell simply divides into two cells by splitting into two parts. This process begins in the nucleus and gradually follows through for the entire cell. A cell is more susceptible to radiation damage during mitosis. If radiation damage to the cell during mitosis does not kill the cell, the two new cells resulting from the cell division may contain abnormalities which will become hereditary for all future cells derived from the abnormal cells.

All cells are not equally sensitive to X radiation. Generally, cells that are slow to reproduce and are highly specialized are the most resistant to radiation. Bone cells and nerve cells are the least radiosensitive of body cells. Muscle cells and skin cells are also quite resistant to radiation damage.

Cells that are not highly specialized and reproduce quickly are the most sensitive to radiation. For example, white blood cells, which have a short lifespan and, therefore, are continually reproducing, come in several varieties and perform several functions. They are not highly specialized cells. White blood cells are the most radiosensitive cells in the body. Another factor that affects cellular radiosensitivity is the rate of cellular metabolism (oxygen consumption). The greater the metabolic activity of the cell, the greater is the cell's radiosensitivity.

F. Determinants of radiation injury

1. Dose rate or intensity (amount of radiation per unit of time)

   Radiation dose rate is important since low dose rates allow time for tissue repair. A dose that would be deadly if given in one short burst to an animal could be given to an identical animal over a long period of time without causing the animal's death. The longer period of time gives the animal's body adequate time to repair the tissue damage. However, some damage always remains after every radiation injury although the damage may be so small as to be undetectable.

2. Specific area involved

The larger the area of the body that is exposed to radiation, the greater is the biological effect on the individual. One thousand roentgen of radiation to the arm during one exposure would result in a severe burn of the skin of the arm and also result in a mild effect on the whole body. The same dose given to the whole body during a single exposure would be fatal.

3. Relative radiosensitivity

Some parts of the body are much more radiosensitive than other parts. The upper abdomen, for example, is more radiosensitive than the leg. The leg is largely bone and muscle; bone and muscle cells are specialized and slow to reproduce and, therefore, relatively resistant to radiation. The upper abdomen contains blood-forming organs, many blood cells, intestinal epithelial cells, and glandular cells; all these cells reproduce rather quickly, are not highly specialized, and therefore are sensitive to radiation.

4. Age

Since radiation damages rapidly growing cells more than it does slower growing cells, one might expect children to be more susceptible to damage than adults from an equal dose of radiation and, indeed, this is the case. However, for older persons, as recovery processes become slower, damage per unit of radiation exposure increases.

5. Variation in response

   a. Species variability. Radiosensitivity varies also with the species. The average dose of radiation necessary to kill a rat is not the same as for a cat or a rabbit, although all three animals are mammals. As a matter of interest, it takes an enormous amount of radiation to kill a cockroach — far more than it does to kill a man.

   b. Individual variability. Within any species there is variability although all individuals might appear to be exactly the same. Each member of a species varies somewhat from his fellows in size, weight, color, intelligence, etc. Each member of a species also varies from his fellows in radiosensitivity.

Some individuals will be much more sensitive than the average and some will be much less sensitive. We can observe this in a group of people at the beach. Some individuals will sunburn quite easily while others can tolerate a great deal of sunlight without discomfort.

G. Short term effects

1. Acute dose

An acute dose is radiation exposure which is delivered to any portion of the body during a very short time. If the amount of radiation involved is large enough, acute doses may result in effects which can manifest themselves within a period of hours or days. The latent period is relatively short and grows progressively shorter as the dose is increased. The signs and symptoms which comprise these short-term radiation effects are collectively known as the acute radiation syndrome.

2. Effects of acute doses

The acute radiation syndrome represents the signs and symptoms which result from large doses of radiation, generally over 100 rads, delivered to a major portion of the body; it is important to recall that this type of injury occurs only when the dose is received over a short period of time. The total effect may vary from mild, transient illness to death. Because of the variation in susceptibility to radiation injury which exists among different individuals, it is extremely difficult to predict with accuracy the degree of effect in a given person, even when the dose is known. The course of the syndrome may vary from hours to several weeks. This time element is generally related to the radiation dose; the larger the dose, the quicker and more severe the illness. The acute radiation syndrome is, of course, not a problem in dentistry.

H. Long term effects

Long term effects of radiation are those which may manifest themselves years after the original exposure. The latent period, then, is much longer than that associated with the acute radiation syndrome. Delayed radiation effects may result from previous acute, high-dose exposures or from chronic low level exposures over a period of years. It should be emphasized that there is no unique disease associated with the long-term effects of radiation; these effects show themselves in human populations simply as an increase of certain already-existing conditions.

It should be noted that, although it is possible to perform experiments with animal populations, human data are limited. Despite this difficulty, many epidemiological investigations of irradiated human beings have provided convincing evidence that ionizing radiation may indeed result in an increased risk of various kinds of illness long after the initial exposure. In other words, what information is available on the effect of radiation on humans confirms the effect it has on animals which have been exposed. Among the long-term effects thus far observed have been cancer, embryological defects, cataracts, lifespan shortening, and genetic mutations.

1. Carcinogenic effects

Anything which can cause cancer is called a carcinogen. X radiation has been shown to have carcinogenic effects on tissues as do certain chemicals and viruses. The radiation exposure necessary to cause cancer is large and usually received over a relatively long period of time. However, no one has ever demonstrated that dental diagnostic radiographs have caused cancer in a patient.

The situation is different in the case of dentists, however. Many dentists have developed cancerous fingers from years of holding X-ray films in the mouths of patients. Dr. C. E. Kells, one of the early dental radiology pioneers was among the first to be affected. He suffered repeated finger amputations and lymph gland removals. Dr. Kells took his own life finally because of these continuing agonies. Many of the early medical radiologists died from cancer induced by massive and continuing doses of X radiation.

2. Embryological effects

Since the fetus is rapidly growing, it is particularly sensitive to radiation. This is true especially in he first three months (first trimester) of a human pregnancy. The tissues are not only rapidly growing but also are relatively unspecialized at this time. For this reason, special consideration should be given to protecting young women in the reproductive ages during radiographic procedures.

3. Cataract formation

If all or part of the transparent lens of the eye becomes opaque, the condition is known as a cataract. When this occurs blindness gradually develops since light cannot then enter the eye. The lens is a tissue considered to be sensitive to radiation and cataracts can develop from excessive radiation. Diagnostic X rays as a form of radiation have not been directly associated with cataract formation, but therapeutic X rays, gamma rays, and certain kinds of particulate radiation have been shown to cause cataracts. Even though dental X rays are not regarded as an important cause of cataracts, it is, of course, nevertheless important to minimize X-ray exposure to the eye as much as practical, because the eye is regarded as a critical organ.

4. Lifespan shortening

In animal experiments it has been demonstrated that the lifespan is shortened by radiation. The animals that have been irradiated appear to die of the same ailments that ordinary animals die of, but at an earlier age. One theory explaining lifespan shortening due to radiation is based on the fact that each radiation insult to the body results in some permanent damage. Each time the individual is irradiated there is damage, and the damage is repaired except for a small amount. Repeated exposures add to this remaining damage, until the total accumulated damage causes the death of the individual. This is the theory which is used to explain the aging process.

5. Genetic effects

Much of our concern is directed toward the genetic (hereditary) effects of radiation. This is because almost all genetic effects due to radiation are considered to be harmful and these effects may be transmitted to future generations. Very low doses of radiation can damage genetic material and the individual suffering such damage is not aware of it. This damage occurs in the form of mutations in hereditary material and can result in defective offspring in succeeding generations.

Men have always lived in a sea of low level radiation. It should be pointed out that everyone's body receives background radiation daily from cosmic rays, from building materials, and from some of the radioactive substances within our own bodies. So nature itself is also responsible for some genetic mutations due to radiation. It is well to realize this in order to give us a sense of proportion regarding man-made radiation exposure.

a. Germ cells. Germ cells are sperm cells in the male and egg cells in the female. Each of these cells contains hereditary material in the form of genes which are linked together in long chains called chromosomes. When the sperm cell fertilizes the egg cell, the chromosomes from each cell combine and together determine what future traits the new individual will have. Thus the whole biological message for a new life – sex, size, shape, health, eye color, skin color, wavy hair, certain personality traits, beauty, intelligence, etc. – is bound up within one tiny fertilized egg cell.

b. Mutations. Mutations are changes or alterations in the nature of a gene which are perpetuated in the hereditary material of a species. For example, a severe mutation could be represented by a baby with no arms or one with six fingers on each hand – both represent an undesirable change in the hereditary pattern. Severe mutations tend to be self-limiting because the offspring die or are incapable of reproducing. Most mutations are not this obvious but are subtle and often may not be thought of as mutations. For example, a tendency to nervous disorders or increased blood pressure, or for low resistance to certain diseases, or a tendency for a malfunctioning digestive system could result from mutations. Such conditions are not necessarily mutations, but may have other causes. Each hereditary trait of an individual is determined by two genes, one from the mother and one from the father. At fertilization, these genes are bonded together and occupy one particular position in the chromosome chain. Each gene may be dominant or recessive, and the combination of these two genes determines the physical traits which the individual will have.

For example, let us assume that dark hair is a dominant trait (H) and blond hair is a recessive trait (h). If both genes are dominant, the individual will have dark hair (HH). If one gene is dominant and one is recessive, the individual will have dark hair (Hh). If both genes are recessive, the individual will have blond hair (hh).

Thus we see that there are two genes for each individual trait. In the next reproductive process, these genes are separated and either one may contribute to the formation of a new individual by combining with the corresponding gene of the other parent.

Recessive traits are evident only when two recessive genes are present. Most mutations are recessive so such changes may not become evident for generations. The individual carries the recessive mutation and passes it on to his or her children. This cycle repeats itself until this particular recessive hereditary material is matched by chance in some future generation with similar recessive hereditary material from some future mate. At this point the mutation manifests itself.

The vast majority of mutations are spontaneous and probably are caused by heat, chemicals, and natural radiation. A great deal remains to be learned about genetics and mutations, so that we cannot always be certain that a particular defect is due to a mutation. We know from animal and human studies that man-made radiation can cause mutations. Geneticists are concerned that excessive exposure of the general population to man-made radiation could lead to an unacceptably high mutation rate — much higher than the spontaneous mutation rate. Most mutations are undesirable and this high mutation rate could be disastrous for the human race.

I. Guides to radiation safety

1. Philosophy

The development of a philosphy of radiation protection is dependent upon an understanding of the effects of radiation on man. In light of our present knowledge, exposure of the human body to X radiation is biologically undesirable. It has been deemed prudent to adopt the conservative hypotheses that there is no radiation dose so small it does not involve some small risk. At the same time it must be recognized that the wise use of X radiation has the potential to confer great benefits to the individual and society. It is, therefore, necessary to balance the possible risk from the use of radiation against the benefits to be gained X radiation should be used so that a maximum amount of diagnostic information is recorded on the radiograph with the least practicable exposure to the patient. The radiation should, of course, be confined to the body area involved, and no other.

Early radiation workers realized that some guidelines would be necessary in working with this new energy, so recommended limits for radiation exposure were developed. As knowledge of radiation exposure hazards increased over the years, the recommended limits were revised downwards several times.

2. Maximum permissible dose — M.P.D.

The maximum permissible doses are recommended limits for radiation exposure. The M.P.D.s are defined as "That radiation dose that should not be exceeded without careful consideration of the reasons for doing so." The permissible exposures are such that, in the light of present knowledge, it is not expected that this amount of radiation will cause detectable bodily injury to an individual during his lifetime. The guides represent doses far below those at which any effects have thus far been observed.

The guides are directed toward both radiation workers and the general public. Radiation workers are those occupationally exposed persons who participate in the operation of X-ray equipment or are likely to be exposed to radiation as a necessary part of their employment. The recommendations are such that no exposure as a radiation worker is permitted to persons under 18 years of age. The general public is allowed a maximum of 1/10 the exposure permitted for radiation workers.

a. Limits for dentists and dental personnel (occupational exposures). Permissible exposure limits for dental personnel are the same as for other radiation workers as shown in Section 30265 of the California Radiation Control Regulations of the California Administrative Code, Title 17, State Department of Health. In the case of a user of radiation whose previous accumulated dose of radiation to the whole body has not been determined, such a person shall not cause anyone, including himself, to receive an occupational dose in excess of: 1.25 roentgens per calendar quarter to the whole body, 5.0 roentgens per calendar year to the whole body, 18.75 roentgens per calendar quarter to the hands and forearms, feet and ankles, or 7.5 roentgens per calendar quarter to the skin of the whole body.

   In some cases, where there has been a prior determination of the individual's accumulated dose to the whole body, the regulations permit an occupational dose greater than the above. However, in the practice of dental laboratory radiography any consideration of radiation dosage higher than those outlined in the paragraph above is entirely inappropriate — in fact, there is no excuse for even receiving exposures of the magnitude outlined above. Radiation received by an individual for dental or medical purposes is not counted in determining his occupational whole body dose.

b. Limits for patients and the general public. The maximum permissible dose for the general population should not exceed 0.5 roentgen per year above natural background and medical radiation. However, exposure of a patient to X radiation should be kept to a minimum consistent with dental requirements.

c. Guidance for students. California Radiation Control Regulations state that "Deliberate exposure of an individual to the useful beam for training or demonstration purposes shall not be permitted unless there is also a medical or dental indication for the exposure and the exposure is prescribed by a physician or dentist."

IV. TECHNICAL FACTORS – EQUIPMENT OPERATION

Technical factors may be classified in two broad categories. The first consideration is the equipment operation and second are the procedures and methods to accomplish a specified result. Chapters VII and VIII will cover the procedural techniques in detail, but first the student should be acquanited with the effects voltage, amperage, focal spot size, target film distance, etc., will have on the quality of the radiograph.

A. Voltage

The operating kilovoltage of the X-ray generator governs the energy of the electron beam which in turn determines the maximum energy of the X-ray beam and its spectral shape as illustrated in Figure II–10. In general, the primary effect of a change in kilovoltage is to change its penetrating ability. The higher kilovoltages produce X rays of greater energy and greater penetrating capability. This has an effect on the radiograph that is produced. Lower kilovoltages produce radiographs with greater contrast while higher kilovoltages reduces subject contrast by levelling out the percentage differences in intensity of the various parts of the radiograph. If the milliamperage was held constant the higher kilovoltage would produce an overall increase of intensity of the radiograph and a change in contrast. If the milliamperage is also adjusted to compensate for the increased kilovoltage only a change in subject contrast will be noted.

B. Amperage

Amperage at which the tube operates is directly related to the intensity of the X rays. Intensity is the number of X-ray photons per unit area per unit of time. Thus it is easy to understand that an increased amperage will cause an increased brightness or intensity of the subject being radiographed. As indicated above, a relationship exists between kilovoltage and amperage in the production of a radiograph and the student must master this interdependency through years of experience before he becomes a master radiographer.

C. Time

Time is the most frequently used variable in dental radiography. The product of milliamperes and seconds (mAs) is milliampere seconds. This indicates the total quantity of X rays generated, and is directly related to the radiograph's specific optical density.

D. Target to film distance

It must be remembered that the intensity of an X-ray beam is related to the distance from the source as discussed in the paragraph on the Inverse Square Law. A change in exposure time is frequently used to compensate for a change in distance. The relationship is given in the following equation.

$$\frac{\text{old exposure time}}{\text{new exposure time}} = \frac{(\text{old distance})^2}{(\text{new distance})^2}$$

E. Focal-spot

X rays are generated at the anode of the X-ray tube but more specifically at the small tungsten element embedded in the anode. This element is called the target. The small area of the target that the electrons hit is called the focal-spot. The focal-spot is the source of the X rays. Since a radiograph is a shadow-graph, the most clear-cut shadow is achieved by smallest practical focal-spot. This is best illustrated by projecting a shadow of one's hand on a wall from a small and large light bulb. The shadow from the small bulb will be relatively sharp, but the shadow from the large bulb will have fuzzy edges. The fuzzy part of the shadow is called the penumbra and the true shadow is the umbra.

The preceeding paragraphs are confined to X-ray tubes having fixed anodes. A more elaborate refinement in X-ray tubes is the rotating anode. This is basically the same tube except the anode is rotated by an electric motor. Rotation facilitates heat dissipation and focal-spot endurance thereby tremendously increasing the capacity for generating X rays. While this type of generator is not commonly used for intra-oral radiography, it is desirable for cephalometric and extra-oral installations.

F. Collimation

Collimation is simply shaping the pattern of the X-ray beam to suit the requirements of a specific examination. Collimation is usually accomplished by placing a lead diaphragm across the X-ray tube's aperture, thus restricting the beam to whatever size or pattern is allowed by the opening in the diaphragm. Collimation may also be accomplished by cones and variable collimators.

G. Film speed

Film speed is the relative ability of the film emulsion to register an image with a given exposure. Refer also to the discussion of film in Chapter III, Section B.1.

For routine dental radiography the use of the fastest available film is preferable. The quality of dental X-ray film is such that little if anything is gained by using slow speed film. This is particularly true where the best methods of technique and processing are employed. There are some special conditions where some benefit may be had from the use of slow film but these should be the exception rather than the rule.

There are also a wide variety of films manufactured for extra-oral use. They fall into two broad categories; the screen film and the nonscreen films. The nonscreen film is made especially sensitive to X radiation and is held in a cardboard or plastic holder. The screen film, while sensitive to X rays, is designed to be primarily sensitive to the flourescence of the calcium tungstate screen.

H. Film deterioration

The film emulsion begins to deteriorate literally from the moment it is made. This fact dictates that the film be exposed and processed during that period in its "life-span" before the aging process detracts from the diagnostic value of the radiograph. This fact is generally known to amateur as well as professional users of film so it only remains to be alert and use a system of consumption which insures that the oldest film is used first. The manufacturers of film cooperate in this respect by dating each box of film so the user has no problem arranging the order in which his film is consumed. The handling and processing of film has a very definite effect upon its quality. Chapter V will consider some detailed aspects of radiographic film.

I. Equipment

All of the above factors have a bearing on the quality of a radiograph and they also are serious considerations for the design and engineering of X-ray equipment.

It will be noted that some of the factors are fixed while others are variable. In some X-ray generators all of the technical factors are fixed by the manufacturer so that the only variable at the technician's disposal is the time factor. This type of equipment is rather elementary and too inflexible for most radiographic laboratories. The more variables designed into a piece of equipment the more elaborate it becomes and usually it is more complex in operation and maintenance. The technician should thoroughly understand all of the technical factors, whether fixed or variable, so that he may best utilize his equipment. The value of such knowledge becomes apparent when one faces the prospect of replacing equipment or where one may have the occasion to design a laboratory facility.

There is a great variety of equipment and material manufactured for X-ray laboratories; the scope of which is much too broad to cover in this manual. However, some examples of typical equipment are illustrated in Appendix C. Two excellent sources of information on equipment are available in most major cities; either the office of the X-ray equipment manufacturer or the X-ray equipment supplier.

J. Exposure charts

The exposure chart is an indispensible guide for every radiographic installation but it is only a guide. There are many hard to define factors, other than the specific factors mentioned in the preceeding paragraphs, which affect radiographs such as:

1. Line voltage differential between various locations of the same type of equipment.
2. The technician's personal operating characteristics.
3. Differing X-ray filtration methods.
4. Minor differences in the manufacture of the same type of equipment.
5. Differences in darkroom quality control.

All of these have a bearing on what exposure factors are best for a particular installation or technician. It obviously is not practical to try to establish one exposure chart to satisy every contingency.

The manufacturers of most X-ray equipment issue manuals giving recommended practices and limitations for their equipment. These will usually include suggestions or guides for specific exposures. This is the best source of information on any given piece of equipment.

It is the responsibility of the technician to evaluate the characteristics of the equipment, then to correlate these facts with his technique and any factors peculiar to his operation. From this point the technician should be able to determine the exposure factors which are exactly right for him. See Figure IV–1 below for an outline of a typical exposure chart.

ADULT EXPOSURE CHART

Technical Factors:

Kilovoltage . . . . As Indicated

Milliamperage . . . . As Indicated

Filtration . . . . 2.5 mm Aluminum Equivalent

Target-Film Distance . . . . 20 inches

Timer . . . . Electronic

Development . . . . 5 min. @ 70 degrees F

Film . . . . Speed, Group D.

MAXILLA **areas**	**mA**	**kVp**	**TIME** **seconds**
Central-Lateral	10	60	0.5
Cuspid	10	65	0.5
Bicuspid	10	70	0.6
Molar	10	75	0.8
MANDIBLE **areas**			
Central-Lateral	10	60	0.4
Cuspid	10	65	0.5
Bicuspid	10	70	0.6
Molar	10	75	0.8

Figure IV–1. Outline of a typical exposure chart.

V. FILM PROCESSING

A. General

Radiographs are often ruined by improper processing or faulty darkroom procedures. An efficient laboratory must have a well-equipped darkroom, adequate space and emphasis on exact and consistent procedures. Whatever the size, the darkroom must have an orderly layout and be absolutely clean.

Many of the procedures in dental laboratory radiography darkrooms are common to those in other dental and medical facilities. Most film manufacturers publish manuals which cover the subject very well. Most laboratories require somewhat larger facilities than those outlined in the brochures, but the materials, safety measures and processing techniques serve as an excellent guide for anyone involved in film processing. These companies also have technical representatives in most metropolitan areas who will help the user of their product with any related problem.

B. Equipment

The equipment will vary with individual laboratories but generally will require larger space and larger equipment than normally used in a dental office. The processing equipment may be manual, automatic, or a combination of these, and should also have the capability of handling any film from the small dental type to 8" x 10" sheet film. Most dental supply houses are able to completely equip a facility and many have staffs able to provide installation recommendations and cost estimates.

C. Film quality evaluation

The student and new technician frequently will encounter unsatisfactory radiographs and often is at a loss as to the cause. An outline of some of the more common faults, their cause, and recommended correction follows:

1. Low density due to underexposure
    a. Kilovoltage too low
    b. Milliamperage too low
    c. Exposure too short
    d. Line voltage drop excessive
    e. Central beam not directed accurately

2. Low density due to underdevelopment
    a. Time too short
    b. Temperature too low (55 degrees F. or lower)
    c. Inaccurate thermometer
    d. Exhausted developer
    e. Chemical activity destroyed by prolonged high temperature
    f. Chemical activity destroyed by contamination
    g. Developer diluted, or improperly mixed
    h. Developer formula deficient

3. High density due to overexposure
    a. Kilovoltage too high
    b. Milliamperage too high
    c. Exposure too long
    d. Excessive surge in line voltage

4. High density due to improper development
    a. Time too long
    b. Temperature too high
    c. Thermometer faulty
    d. Improper formula for developer

5. Film fogged by light
    a. Improper safelight
    b. Light leaks in darkroom
    c. Sparking of motors from ventilating fans or dryers
    d. Improper safelight filter; filter too old, cracked or shrunken
    e. Luminous clocks or watches

6. Films fogged by radiation
    a. Faulty storage or transportation
    b. Inadequate shielding
    c. Improper handling and storage of radioactive substances or equipment

7. Film fogged by chemical action
    a. Developed too long
    b. Developer contaminated
    c. Old film; oldest dated film should be used first
    d. Storage area too hot
    e. Storage area too humid
    f. Ammonia fumes present in darkroom
    g. Excessive pressure on emulsion of unprocessed film
    h. Loaded cassette left in sunlight or near heating system

8. Stains on radiographs
    a. Exhausted developer
    b. Exhausted fixer
    c. Impure water used for chemical mix
    d. Insufficient rinsing

9. Metallic deposits on radiographs
    a. Oxides from developer
    b. Silver deposit from overloaded fixer
    c. Dirt in water or dryer

10. Streaks on radiograph

    a. Insufficient fixing
    b. Weak fixer
    c. Fixer neutralized by developing solution
    d. Drying temperature too high
    e. Contact with foreign object while drying
    f. Contact with hot viewing box

11. Blisters on radiograph

    a. Chemical reaction of developer and fixer; rinse film thoroughly in transfer to fixer
    b. Temperature differential between developer and fixer is excessive

12. Reticulation

    a. Temperature differential between developer, rinse and fixer is excessive
    b. Weakened fixer with deficient hardener

13. Air bells (round white spots on radiograph)

    a. Air bubbles trapped on film surfaces which prevent development
    b. Dropping film into developer without agitation

14. Brittleness of finished radiograph

    a. Drying temperature too high
    b. Excessive drying time
    c. Excessive hardener in fixer

15. Static electricity (see Appendix A14)

There are two ways to avoid static marks on film. One is to prevent the generation of the charge; the other is to provide a path for such a charge to leak off once it is formed.

a. Controlled humidity is probably the best deterrent (relative humidity should be between 50 and 75 percent)

b. Handle film gently. Lift interleaving paper off carefully. Do not slide off sharply.

c. Do not slide film across any surface.

d. Open and close cassettes carefully.

e. Avoid clothing and floor coverings which allow static charges to develop. Rubber floor tile and hard floor waxes are sometimes a source of trouble.

VI. DENTAL ANATOMY

A good radiograph is so dependent on one's ability to visualize anatomical features that definite knowledge and a clear understanding of certain aspects of dental anatomy are particularly important. The student and the technologist will be constantly involved with a complex process of visualizing anatomical features and projecting them onto film. For those who have a natural ability in graphic visualization the process is not so confusing but for those who must acquire this ability it is important to proceed one small step at a time. Therefore, first learn the proper names of the teeth; refer to Figure VI-1.

A. Dentition

1. Maxilla

It should be helpful to note that the dentition (the teeth and their supporting structures) are divided into four quadrants. The maxilla (upper jaw) comprises two of these quadrants: a right side and a left side. Note also that in viewing a patient, a dental diagram, or a dental chart the sides are designated as they appear to the viewer. For example, as the technician faces a patient's mouth, the patient's right is on the technician's left side. This practice is followed throughout these instructions.

Each of the maxillary quadrants have similar teeth. Beginning at the midline you will note in Figure VI-1:

a. Central Incisor
b. Lateral Incisor
c. Cuspid
d. First Bicuspid
e. Second Bicuspid
f. First Molar
g. Second Molar
h. Third Molar

These comprise all the teeth in one quadrant of a normal adult mouth. The opposite quadrant has the same composition.

2. Mandible

The mandible has a composition of teeth which are, structurally and functionally, very much like those in the maxilla. The mandible, like the maxilla, is divided into a right and a left side. A careful look at the teeth in the right mandible as compared to those in the left mandible reveals that the right and left central incisors are almost indentical, as are the corresponding cuspids, bicuspids and molars. The same is true of the teeth in the right and left sides of the maxilla. Comparing the teeth in the maxilla with those in the mandible it will be noted that opposing incisors, cuspids, bicuspids and molars have very marked similarities. There are some differences particularly in the root structures and cuspal patterns. For radiographic purposes we look at the mandible as having a right and left side with the following teeth:

a. Central Incisor
b. Lateral Incisor
c. Cuspid
d. First Bicuspid
e. Second Bicuspid
f. First Molar
g. Second Molar
h. Third Molar

The similarities in dentition make the learning process somewhat easier since we can reduce the learning of thirty-two teeth to eight types of teeth; central incisors, lateral incisors, cuspids, first bicuspids, second bicuspids, first molars, second molars and third molars.

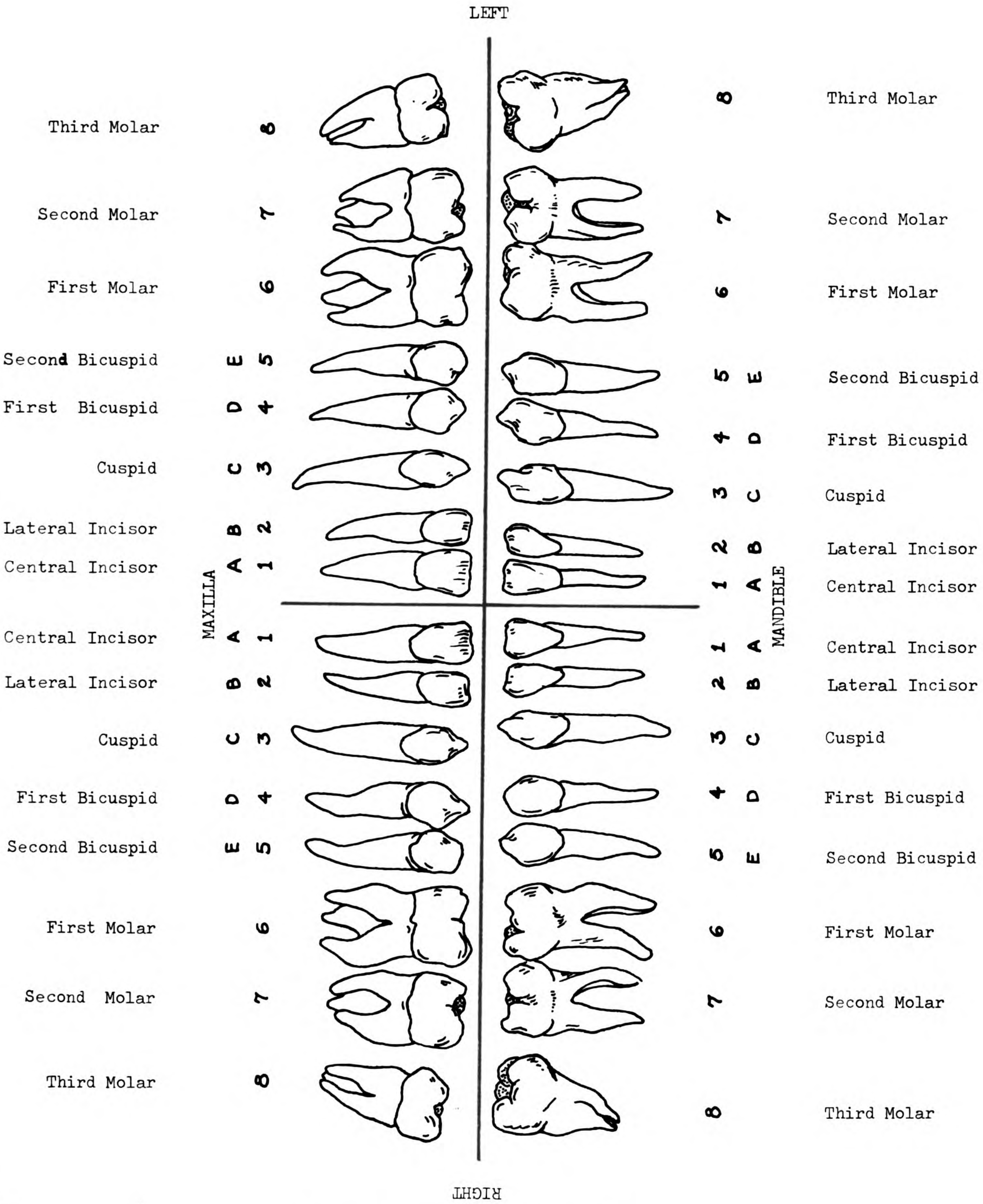


Figure VI - 1 -- Names of the teeth.

The differences which we learn with progressive learning make it possible to visually separate the teeth of the maxilla from those of the mandible. For example, looking at Plates 6a and 7a (Appendix A) and Figure VI-2, it is apparent that even at a casual glance the maxillary incisor is different than the mandibular incisor. They are different in size, and contour but they are both functionally incisors. To observe the differences further it will be seen that the maxillary molar (first) differs from the mandibular first molar in size, contour and structure. The structural difference is obvious in the number of roots. If the student is alert in observing these and similar differences, particularly in the radiographs, in a very short time the identity of any tooth becomes almost automatic.

3. Dental Chart - Radiographic
(See Figure VI-2.)

Dental Charts are a most useful device for transmitting information and keeping records. They save time and ambiguities in communicating from one office to another. There are various types of dental charts but basically they use a diagram of the upper and lower dental arch showing each of the normal teeth in their relative positions. Other elaborations are used to suit individual needs. A system of numbers and letters is also used in conjunction with the diagram. The numbers represent the permanent teeth and the letters the deciduous teeth. One system uses numbers beginning with the upper right third molar designated No. 1 and running clockwise around the upper and lower arch to No. 32 at the lower right third molar. The other system employs the quadrant concept where the maxilla is divided into a right and left quadrant along with the mandible which is also divided into a right and left quadrant. Then, beginning with the central incisor in each quadrant and moving distally to the third molar, the teeth are numbered from one to eight. This is more compatible with the quadrant concept previously described and is preferred here for the sake of consistency. (See Figure VI-2.)

This is a very basic element for dental communication so the student should commit the chart to memory.

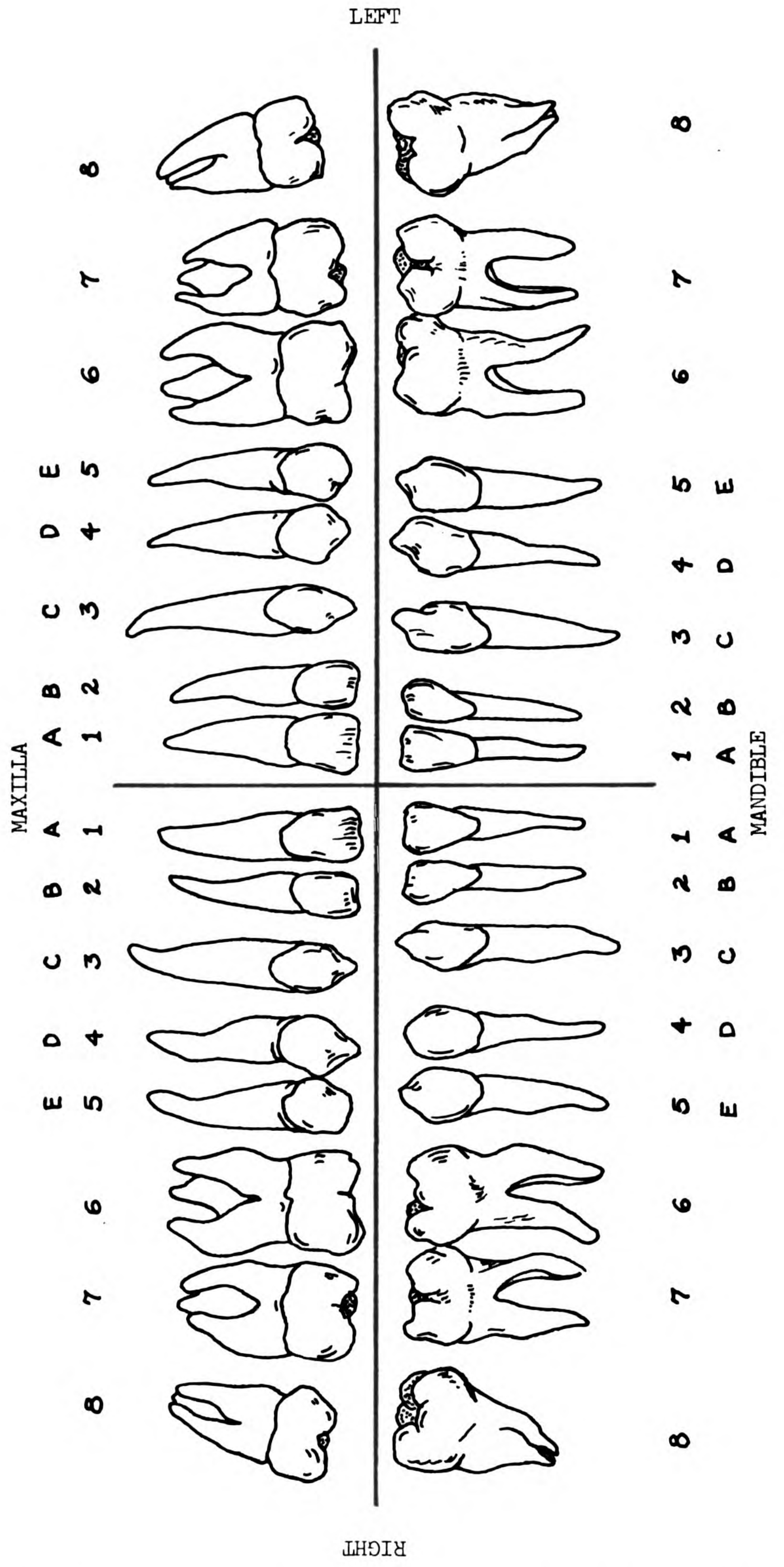


Figure VI - 2 -- Dental Charts for record keeping

B. The Head

(See Figures VI-3, VI-4, VI-5, and VI-6 and Appendix A, Plates 11, 12, 13, and 14.)

The dentition is an integral part of the head. It is not possible to isolate ourselves with strictly dental structures and still practice competent dentistry. This is particularly true in surgical and orthodontic considerations and these, in turn, reflect their requirements upon dental radiography. In cephalometrics the technician will be concerned with the entire head; in other radiographs he will be concerned with only a portion of the head or jaws, such as in a lateral jaw or occlusal radiograph.

In order to understand the procedures and, equally important, to be able to evaluate the radiograph, it is imperative that the technician have some knowledge of the head. These instructions will be limited to briefly outlining those features and indentification points which are considered minimal requirements for dental radiography. There are many sources for expanding one's knowledge on this subject and obviously any such expansion will enhance the technician's competence.

1. Reference Points

(See Figure VI-3 and VI-4.)

Just as it is important for purposes of study and communication to have references such as the nose and eyes, it is even more important in radiography to have references which are not so obvious. The head and face have literally thousands of identifying features but we will be concerned with just a few which will enable the student to understand the text and become prepared to evaluate pertinent radiographs.

Figure VI-3 shows a profile drawing of the human skull with characteristic features of a lateral head radiograph. Several indentification points are designated and should be committed to memory.

Figure VI-4 is a drawing showing the front aspect of the skull. This will show some reference points which are not as easily indentifiable in the profile view and will also repeat some which are common to both views. It might be useful to refer to Plates 11, 12, 13, and 14 (Appendix A) for a comparison of some of these points and features.

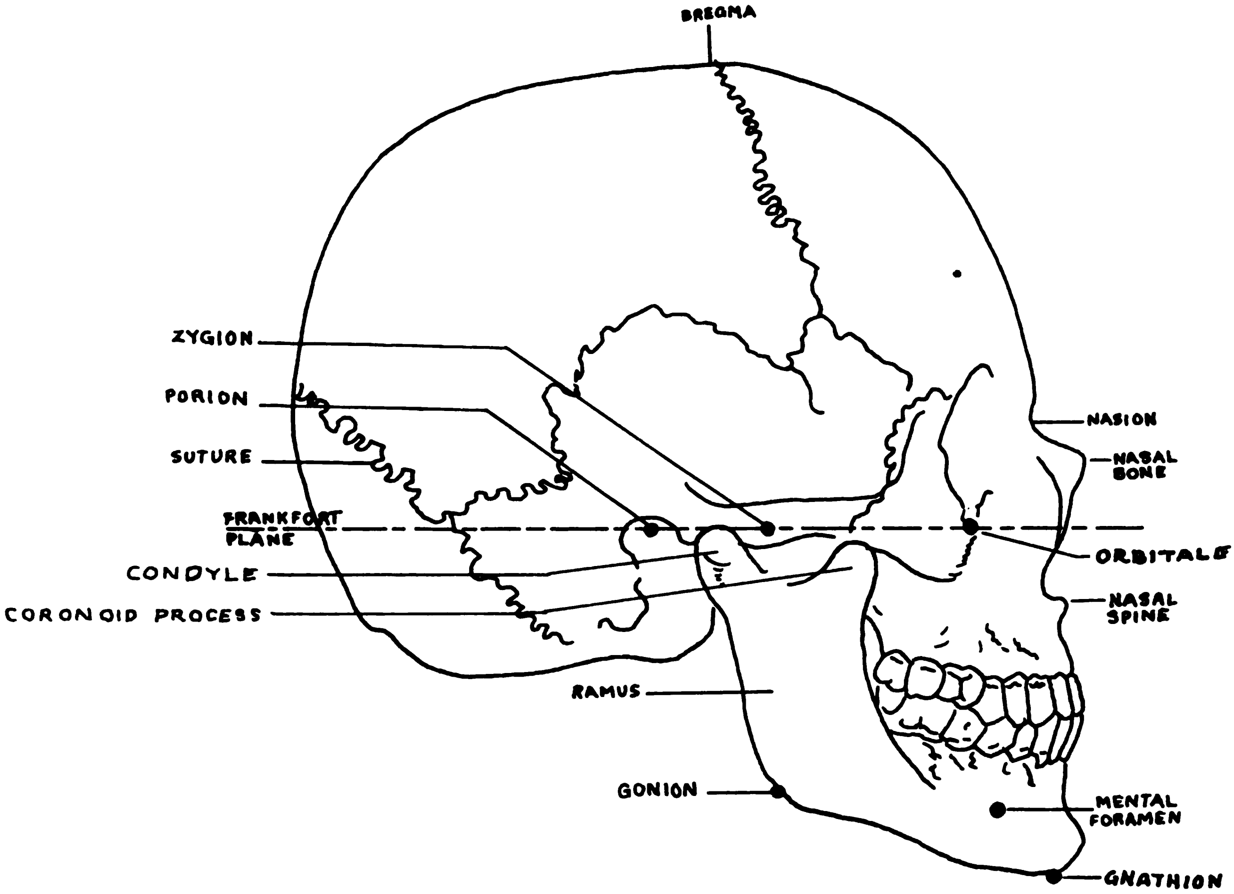


Figure VI - 3

Profile of the human skull

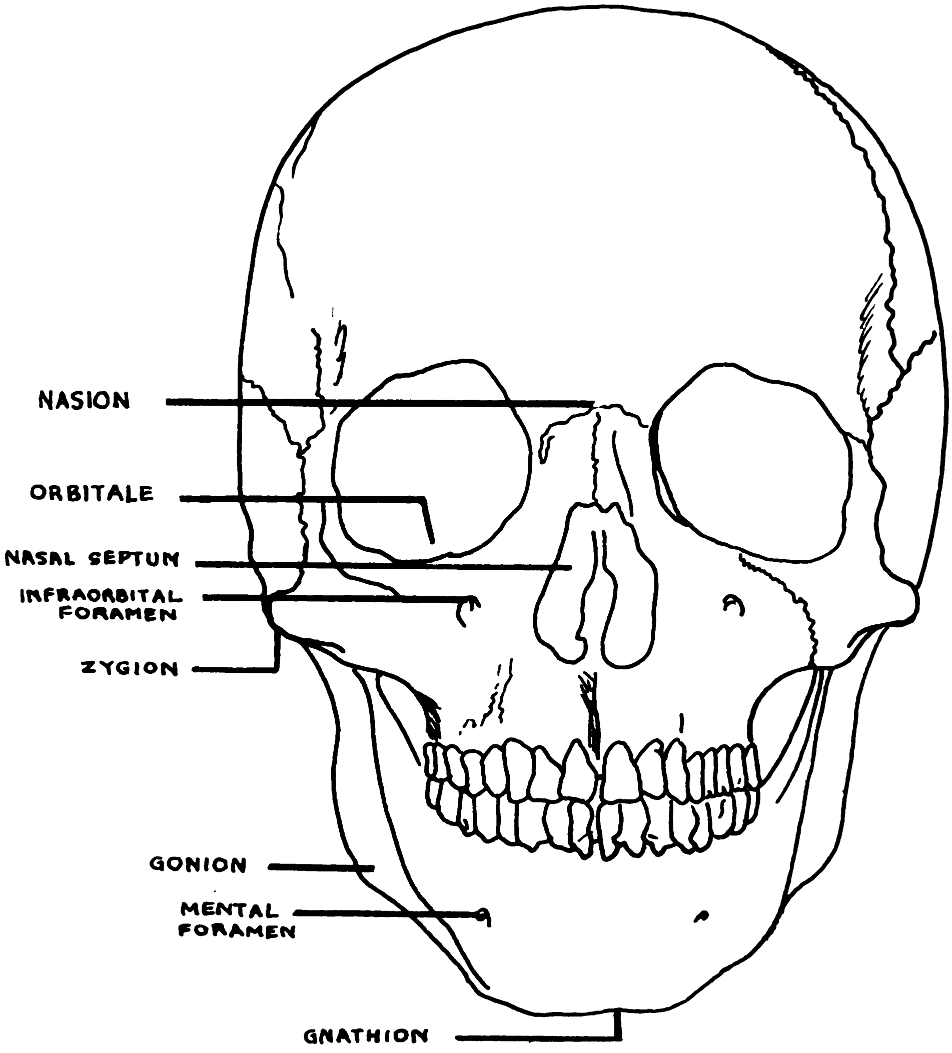


FIGURE VI -4 -- Front Aspect of the human skull

2. The Sagittal Plane.
(See Figure VI-5.)

It is hardly necessary to point out that the head is commonly considered to have a right and a left side. Figure VI-5 is a pictorial view of a plane drawn through the long axis of the head dividing it into the right and left side. The shaded area represents a visual concept of this plane. The circular insert at the top of the page shows how this plane would appear when viewed from the top of the head. Visual concepts are an indispensible implement for good radiography so the technician should develop an indelible picture of the several planes which are discussed here. They will be encountered frequently and are basic to the geometry of projecting radiographs. The shaded area is a precise plane of reference and has a name; the mid-sagittal plane. Any other section through the head which is parallel to this one is known as a sagittal plane. The line on the face or its extension to the bony surface of the skull is commonly referred to as the mid-line.

3. The Occlusal Plane.
(See Figure VI-6 and Plates 8 and 9 Appendix A.)

The occlusal plane is another reference which will be encountered frequently. Figure VI-6 shows a shaded area which visually depicts the occlusal plane as it would be extended beyond the confines of the mouth. Usually we are concerned with the occlusal plane as it relates to the interior part of the mouth but it is useful to extend this visualization as projected in Figure VI-6. Two other planes are represented on this drawing to show how they are interrelated. Theoretically the sagittal plane is perpendicular to the occlusal plane and the orbital plane is parallel to the occulsal plane. The circular insert shows a side edge-view of the occlusal plane.

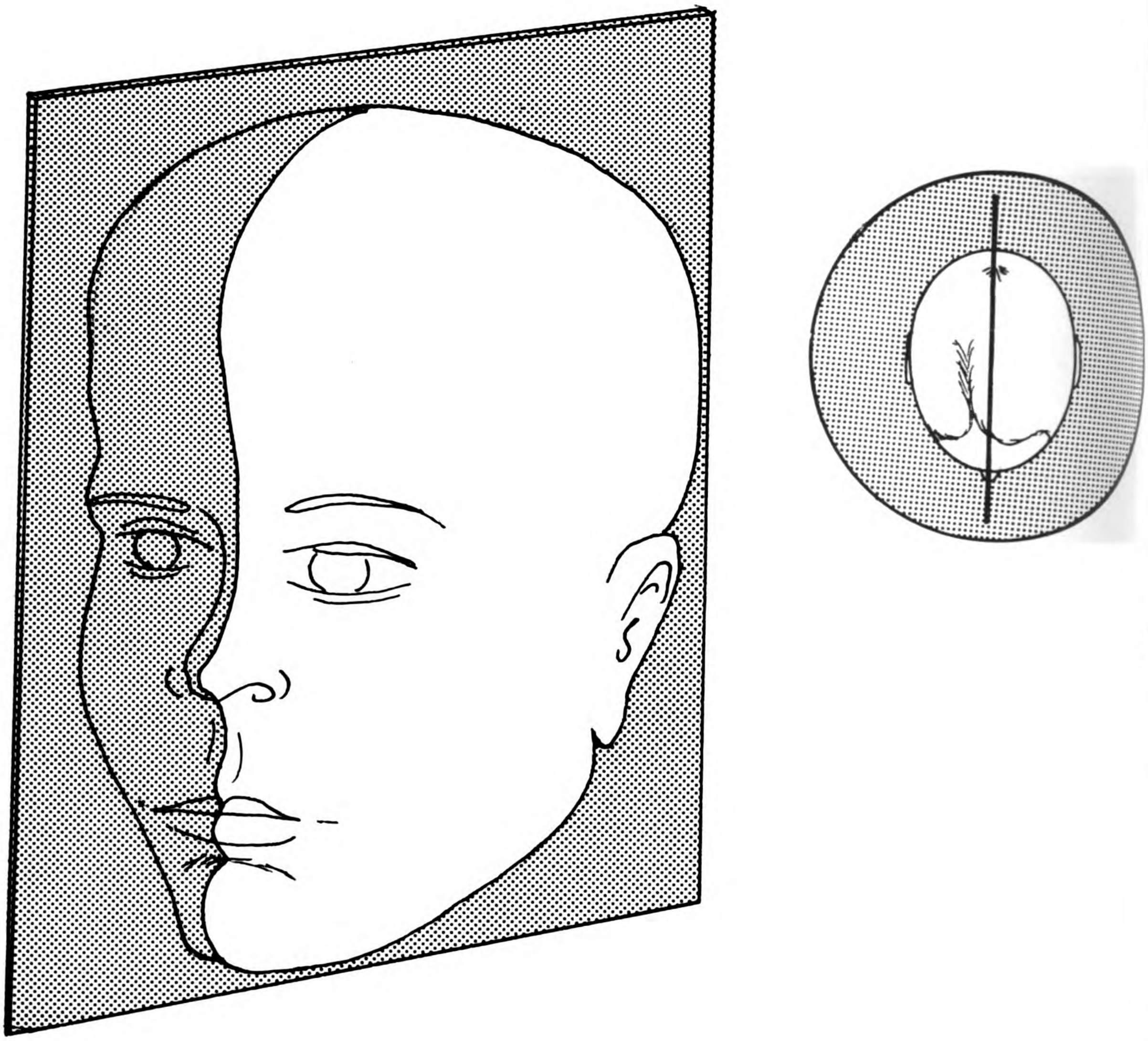


FIGURE VI - 5 -- The Mid-Sagittal Plane.

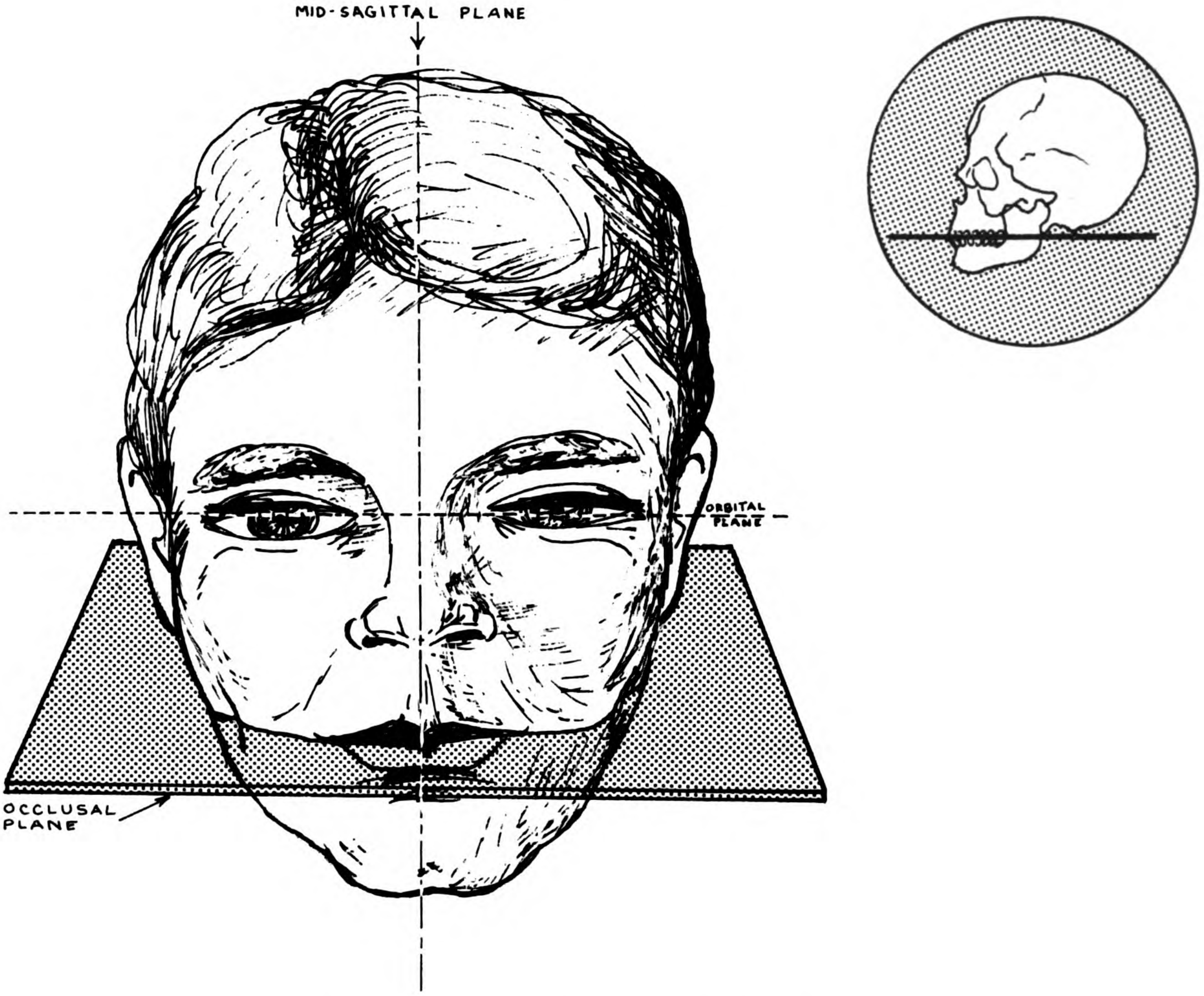


Figure VI - 6 -- The Occlusal Plane.

VII. DENTAL RADIOGRAPHIC PROCEDURES & TECHNIQUES

A. Intra-Oral Procedures

1. Equipment and Aids

It is not the intention of these instructions to undertake a detailed discussion of all the equipment and tools used in dental laboratory radiography but rather to make the student aware that certain elements are necessary for good results.

There are a number of manufacturers of dental radiographic equipment; some of which are listed in Appendix B. There are also a number of auxiliary pieces of equipment and many items which are probably better classified as aids.

Some of the major pieces of equipment for dental laboratory radiography are listed below:

a. The X-ray Generator is the prime piece of equipment in radiography.

b. A well equipped darkroom should be considered as a unit rather than so many individual pieces. Your dental supplier is an excellent source of information.

c. A dental chair of the exodontia type which may be rotated 360 degrees is preferable. In order to position the patient properly and to have the flexibility for performing the examinations required by modern dentistry it is necessary to have a chair approximating this type. Many kinds of this type of chair are available from dental equipment suppliers.

d. Film holders are not only necessary to achieve proper object-film relationships but also to contribute to the patient's comfort and the technician's speed in completing some procedures. Many types of holding devices are available. Most of them are adaptable to the following procedures. Some are shown in Appendix C-1.

e. Cassettes (8" x 10" or 10" x 12") are covered in dental manuals. These are general purpose film holders with intensifying screens. They are necessary for cephalometric, lateral head, lateral jaw, and temporo-mandibular-joint type radiographs.

f. Intra-oral cassettes with intensifying screens are not as common but indispensible for good results in topographical type surveys. They also help to minimize the amount of radiation in achieving the same result in some special examinations. These cassettes are not as readily available but most dental equipment suppliers can order them.

g. A well designed cephalometer is necessary for satisfying orthodontic requirements. This is essentially a graphic measuring device, so the component parts of the cephalometer must have the capability for accurate alignment. See Appendix C-5.

h. Office and reception furnishings and equipment are those standard to most dental offices and can be as elaborate or as modest as suits the particular office.

2. Geometric Principles of X-ray Projection

Some simple principles of geometry and the theory of projection should be reviewed in order to understand the techniques which follow.

a. In producing radiographs we are always concerned with three basic elements and their relationship to each other;

    (1) Source of radiation (X-ray generator) and more precisely its focal spot. The focal spot should be as small as possible to give the sharpest image.

    (2) The object; in this case usually dentition.

    (3) The film.

    The manner in which the technician arranges these three elements determines type and quality of radiographic product.

b. The techniques which follow are based on a simple fundamental concept; sometimes called the parallel planes technique See Figure VII-1.

    (1) Film placement is parallel to the plane of the object, and as near as is practicable.

(2) Central-beam is directed perpendicular to the plane of the object.

(3) Use the optimum target (focal spot) film distance.

Refer to Figure VII-2 where a, b, c, and d, represent different object, film and central-beam relationships. In "a" the object and film are parallel and the central beam is perpendicular, resulting in the most accurate projection where all other factors are equal. In "b" the object remains in the same position but the film is not parallel resulting in an elongated image. In "c" the film is perpendicular to the central-beam but now the object is not parallel and results in distortion. In "d" the object and the film are once again parallel but now the central-beam is no longer perpendicular which again results in a distorted image. This concept is simple, but rigid discipline is required, at least initially, until the perfomance becomes automatic.

The following illustrations show what happens in a vertical dimension. It should be remembered that the same principles apply to the horizontal dimension. There may be cases where it is necessary to vary one dimension while maintaining the other constant.

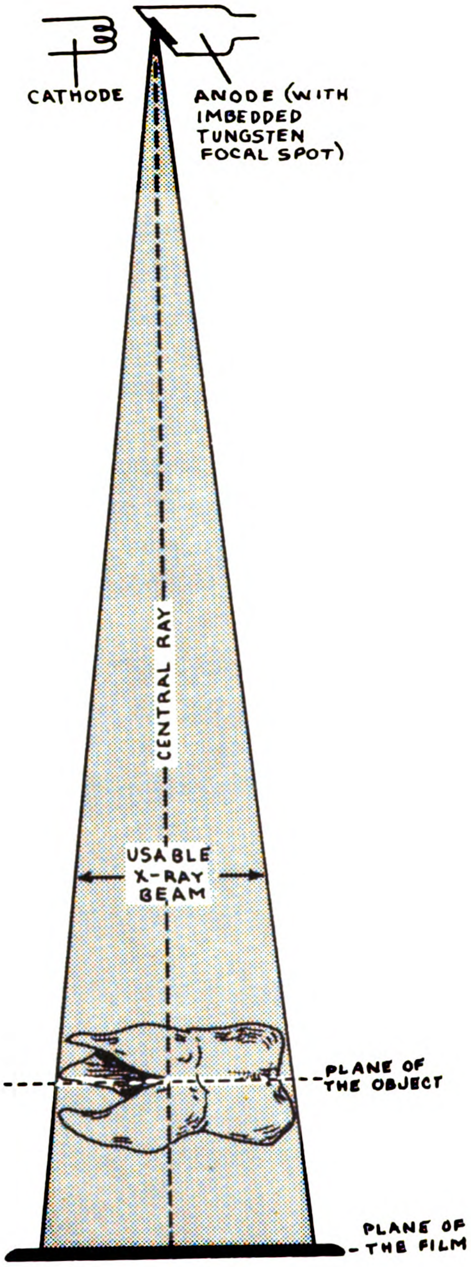


Figure VII -1 -- The parallel plane technique in radiography.

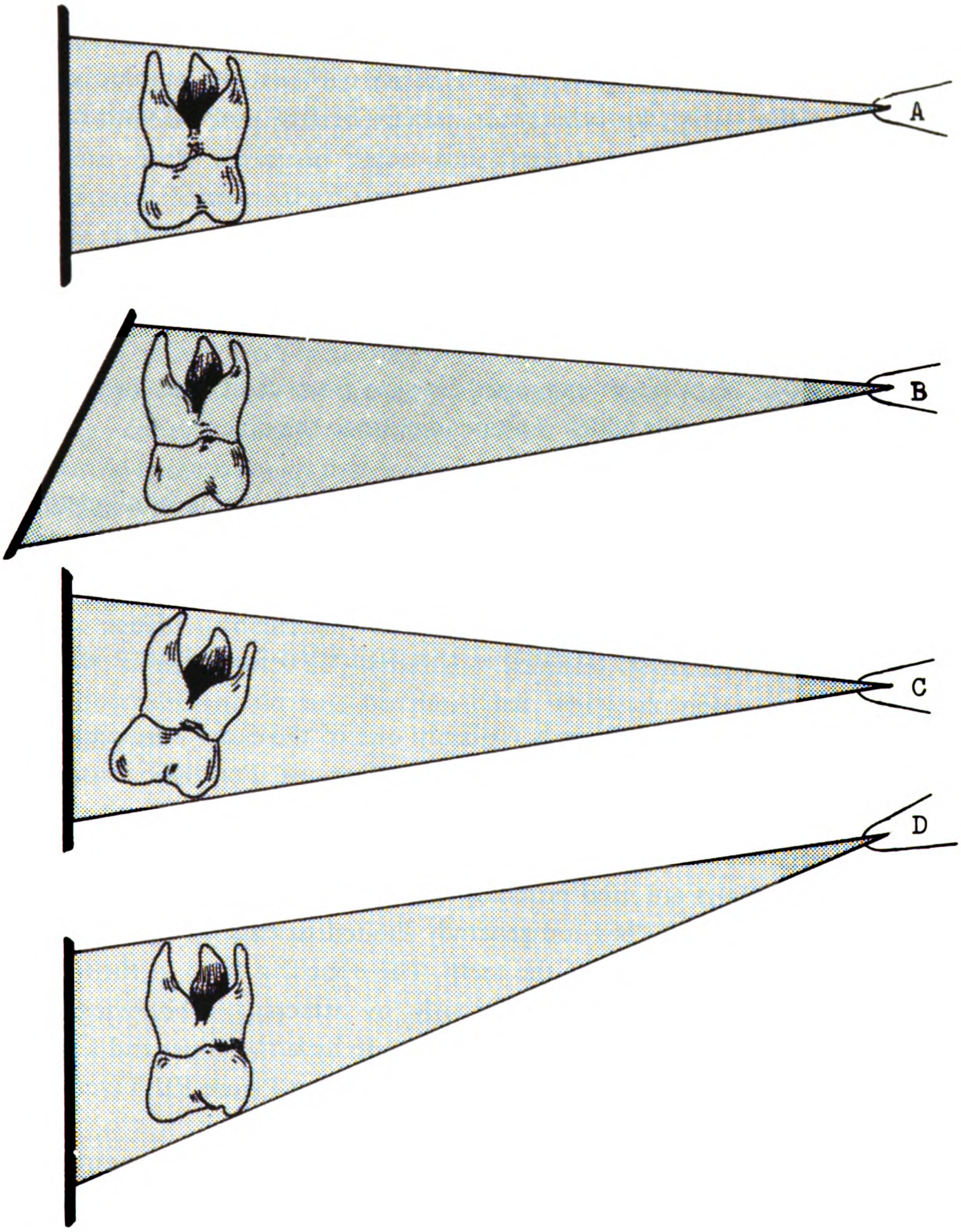


FIGURE VII -2 -- Object, film and central beam relationships.

3. Visual Concepts in X-ray Projection

The foregoing principles are fundamental to every dental radiographic projection. However, it is one thing to outline this concept with paper and pencil but quite another thing to produce it radiographically. Another element is introduced at this point; the visual element is stressed in the discussion on anatomy. The technician must now be prepared to correlate his knowledge of anatomy, specifically the plane of the object, with the three principles of the parallel-planes-technique. For those with natural graphic abilities this comes rather easily; for others it is perhaps best to proceed with some kind of outline such as follows:

a. Visualize plane of object

b. Place film parallel to plane of object

c. Place target at proper distance from object and direct the central-beam at an angle which is perpendicular to the object

By following the geometric principles and keeping in mind the visual concepts outlined the student can readily acquire a pattern of operation, or technique, which will insure consistently good radiographs.

4. Bite-Wing Survey Technique (See figure VII-3 and Plate 1 of Appendix A)

The bite-wing survey is probably one of the easier intra-oral techniques and one of the most commonly used examinations. For these reasons it is probably a good starting point for the new student.

Bite-wings are used primarily for revealing caries, calculus, and the condition of restorations. They are generally limited to examining conditions of the crowns and gingival areas of the teeth. The opposing teeth in the maxilla and mandible are radiographed simultaneously by attaching a bite-wing tab to a standard periapical film in such a manner as to have the upper and lower crowns exposed when the tab is held between the teeth. See Figure VII-3 (vertical view.)

For a complete bite-wing examination of adults the mouth is usually divided into the bicuspid and molar areas. It is imperative that the radiographs show the interproximal spaces open in these examinations.

The film packet for the bicuspid bite-wing is placed to show the distal contact of the cuspid, the first and second bicuspid, the first molar and usually all or a portion of the second molar. The central-beam is directed, horizontally, between the first and second bicuspid; vertically the angle should approximate +5 degrees. Contacts between the cuspid, bicuspids and probably the first molar will be open on this view. See Plate 1 a, b, c, and d, Appendix A.

The radiograph for the molar area is placed to show a distal portion of the second bicuspid, the first and second molar and all or most of the third molar or third molar area. The central-beam is directed between the first and second molar with a vertical angle somewhere between 0 degrees and +5 degrees. Contacts between the first, second and third molars will usually be opened on this view.

Where good alignment of the teeth is present these views, two on each side, should show all contacts open from the distal of the cuspid to the distal of the third molar in both the maxilla and mandible. Where any overlapping of contacts may conceal caries, additional views should be taken by directing the central-beam through that particular interproximal space with a horizontal angle which will separate the contacts. There are extremely few dental contacts which will not yield to this method.

For deciduous dentition one radiograph on each side will suffice for most cases. Two films should be considered standard procedure. However, additional radiographs should not be precluded whenever necessary to open difficult contacts.

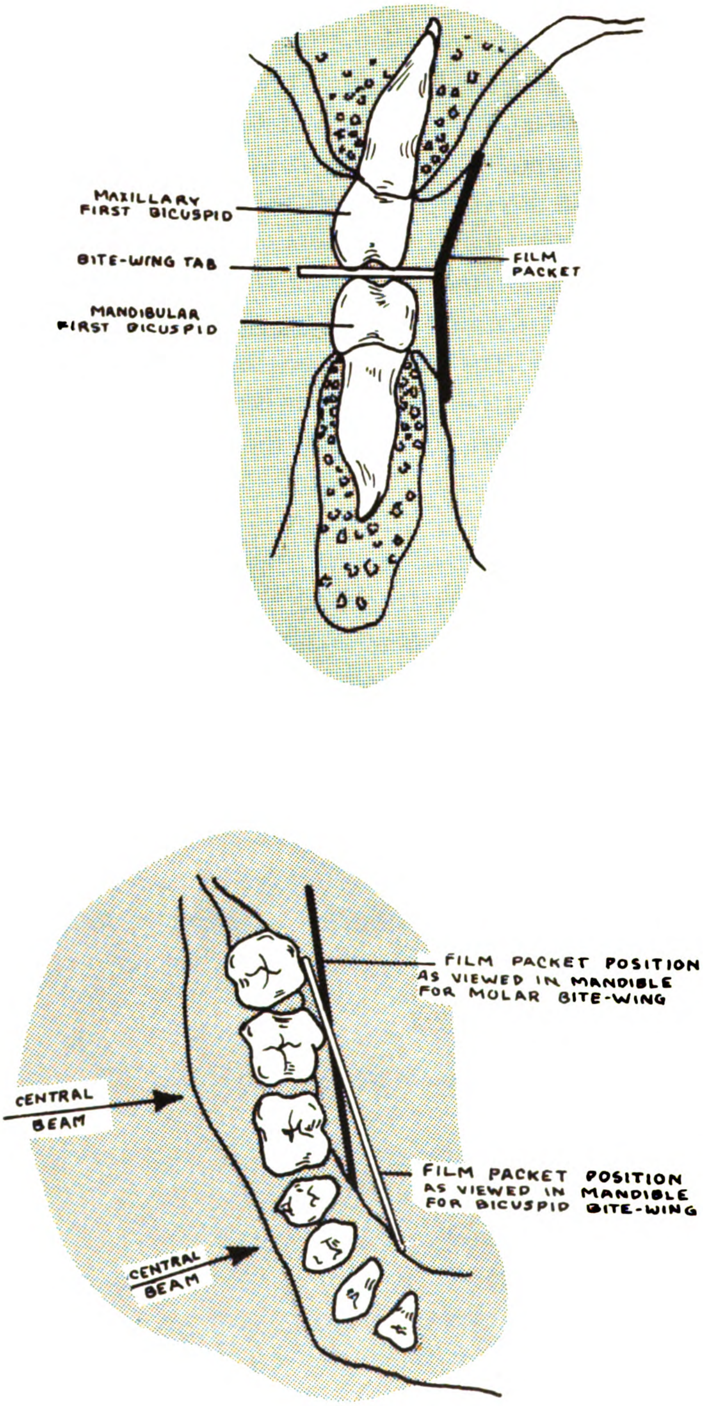

MAXILLARY FIRST BICUSPID
BITE-WING TAB
MANDIBULAR FIRST BICUSPID
FILM PACKET
FILM PACKET POSITION AS VIEWED IN MANDIBLE FOR MOLAR BITE-WING
CENTRAL BEAM
FILM PACKET POSITION AS VIEWED IN MANDIBLE FOR BICUSPID BITE-WING
CENTRAL BEAM

Figure VII -3 -- Bite-Wing technique.

a. Area of Examination

  (1) Bicuspid Bite-wing: Distal portion of cuspid, crowns of first and second bicuspid, first molar and all or a portion of second molar crown.

  (2) Molar Bite-wing: Distal portion of second bicuspid,
  crowns of first and second molars, and all or a portion of third molar crown or area.

  (3) See Figure VII-3 and Appendix A, Plate 1.

b. Film Size

  (1) 3.2 x 4.1 centimeters for adults.

  (2) 2.4 x 4 cm for children.

  (3) Bite-wing type 2 or type 3 film if preferred.

c. Film Exposure

  (1) Refer to film exposure guides and equipment manufacture's recommendations

  (2) See Technical Factors, Chapter IV.

d. Film Placement

  (1) Bicuspid bite-wing placed to show from distal of cuspid.

  (2) Molar bite-wing placed to show from distal of second bicuspid.

  (3) For deciduous teeth one film may suffice on each side, showing distally from cuspid.

e. Film Retention

  (1) Bite-wing tab held securely between patient's teeth.

f. Angulation and Central Beam

(1) Bicuspid bite-wing: Central beam aligned horizontally with proximal surfaces of bicuspids. Vertical angle approximately five degrees.

(2) Molar bite-wing: Central beam aligned horizontally with proximal surfaces of first and second molars. Vertical angle variable between 0 degrees and +5 degrees.

5. Periapical Technique for the Maxilla

a. Maxillary Central and Lateral Incisors (See Figure VII-4 and Appendix A, Plate 6-A.).

The maxillary central and lateral incisors are probably somewhat easier to radiograph than some of the other dentition so for this reason they are selected as a starting point for periapical type projections. The incisors are more readily accessible for placement of film and supporting devices. This is particularly true of the vertical dimension but it will soon be observed that the horizontal dimension is notably restricted in many mouths. As explained in other parts of this manual, two sizes of film are generally available for periapical examinations. The film size 3.2 x 4.1 cm (1-¼ x 1-5/8th inches) is commonly used for posterior teeth while the film size 2.4 x 4 cm (15/16th x 1-9/16th inches) is used in the confined areas such as the anterior teeth. These films are identical in every respect except for their dimensions.

One of the basic concepts in radiographic projection is the parallel relationship of object and film. It should be noted that although the incisors are more easily accessible they are more deceptive in visualizing the plane of the teeth because of the coronal contour. A common fault is to visualize the plane of the tooth in respect to the crown rather than the entire length of the tooth. See the dotted line in Figure VII-4. The central and lateral incisor are projected as a unit since in combination they satisfy the requirements for this concept. Refer to Plate 6-A, Appendix A. It might be argued, by carrying this concept to absurdity, that it would be better to project each tooth separately. However to carry the argument to that point would defy the need for keeping radiation to a minimum and would mock our need for economy of material, effort and a practical solution.

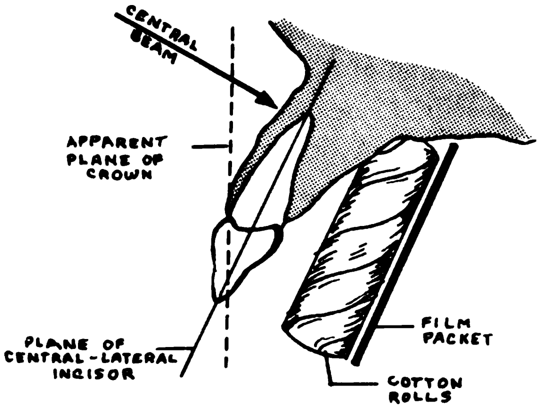


Figure VII -4 -- Determining the plane of the incisors. A common fault in determining the plane of incisors is a failure to understand the anatomy of the anterior dentition. The dotted line represents the plane arrived at by sighting on the crown of the incisor. The solid line represents the proper plane through the long axis of the incisor.

The central-lateral incisor should be projected so that it appears centered on the film. This approach not only lends itself to the esthetic value of the result, but also as a practical matter helps in the development of a consistent and uniform technique. This projection should reveal, in addition to tthe entire central-lateral and supporting structure, a mesial portion of the adjacent central incisor, mesial portions of the cuspid, portions of the median suture line, and probably the incisive foramen. Refer to Appendix A Plate 6-A and Figure VII-5.

The contour of the palate and location of the incisors lend themselves nicely to employing the patient's thumb for film retention. Using the narrow film (2.4 x 4 cm), two No. 3 cotton rolls are fitted along the long axis of the film on the tube side of the film. See Figure VII-5. The film and cotton rolls are then positioned on the lingual side and parallel to the long axis of the incisors. At this point the operator should make visual sighting which will assure him that the projected image will be centered and that about 2mm of film remains as a margin below the incisal edge. The patient's thumb (use hand on opposite side being radiographed) is then placed gently but firmly against the film packet to retain proper object-film relationship until exposure has been completed. A third cotton roll may be used to prop the film away from the incisal edge. Having properly positioned the film, the next consideration is the projection of the X-ray beam. As previously noted under the heading of geometric principles a proper projection depends on vertical angulation, horizontal angulation and location of the central-beam. In this instance vertical-horizontal angle should be perpendicular to the plane of the film (or the plane formed by the long axis of the incisors) with the CB (central-beam) directed at the apices of the teeth. A line visualized from the ala of the nose to the tragus of the ear may serve as a guide for locating the apices.

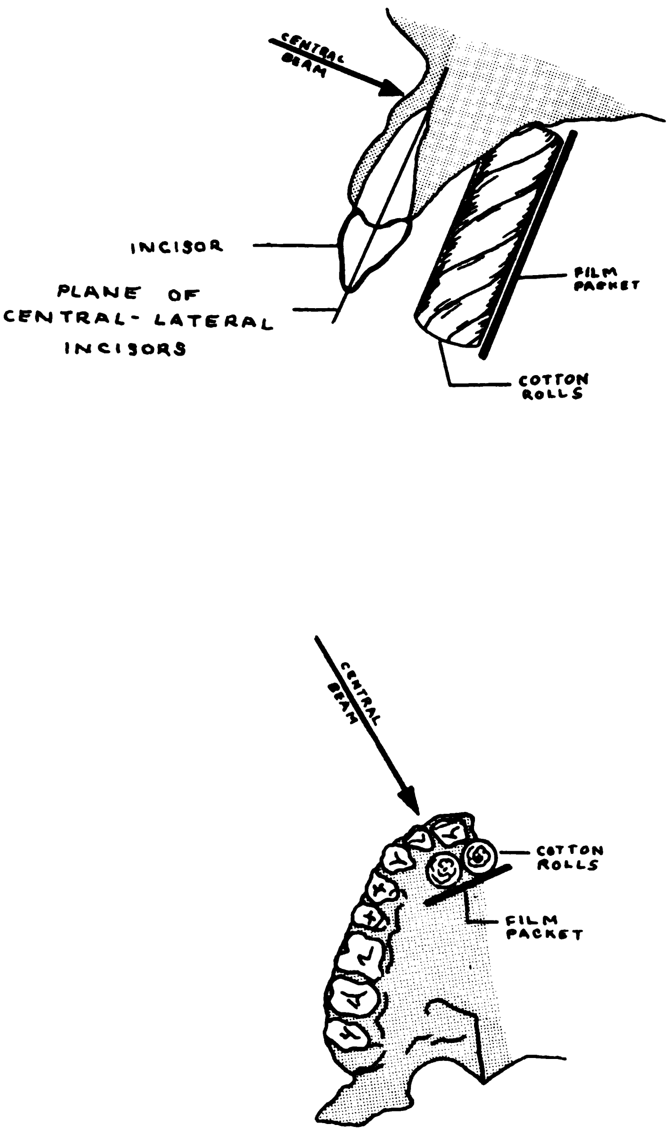


FIGURE VII -5 -- Central-Lateral Incisor Projection (Maxilla)

(1) Area of Examination

    (a) Entire Central Incisor with margin over apex

    (b) Entire Lateral Incisor with margin over apex

    (c) Mesial portions of adjacent central incisor and cuspid

    (d) Contiguous supporting structures

    (e) See Figure VII-5 and Appendix A, Plate 6-A.

(2) Film Size

    (a) 2.4 x 4 centimeters (usually)

    (b) 3.2 x 4.1 centimeters where appropriate

(3) Film Exposure

    (a) Refer to exposure guides and equipment manufacturer's recommendations

    (b) See Technical Factors, Chapter IV

(4) Film Placement

Film centered on lingual surface of central-lateral incisor and positioned parallel to long axis of plane formed by incisors.

(5) Film Retention

    (a) Two No. 3 cotton rolls on surface of film (tube side)

    (b) Patient's thumb. (Use hand on opposite side.)

(6) Angulation and Central Beam

    (a) Vertical and horizontal angle perpendicular to film.

    (b) Central beam (CB) directed through proximal surface of central and lateral. Where overlapping occurs, visualize normal contact point and project accordingly.

b. Maxillary Cuspid. See Figure VII-6

The intra-oral procedure for the central-lateral projection is essentially applicable to the cuspid. Using the narrow film (2.4 x 4.0 centimeters) and two No. 3 cotton rolls, the cuspid should be projected onto the center of the film. This film will show the entire cuspid and portions of the adjacent lateral-incisor and bicuspid. Portions of the nasal sinus and the anterior wall of the maxillary sinus are also characteristic landmarks on this projection. The contact between the lateral incisor and the cuspid will usually be shown open on a good projection of the cuspid. However in respect to the bicuspid because of its bucco-lingual dimension the contact with the cuspid will usually be closed.

For film retention follow the procedure outlined under the central-lateral incisor projection.

As in the central-lateral projection, the X-ray beam is arranged perpendicular to the plane of the film (or cuspid) and directed through the middle of the cuspid. See Figure VII-6.

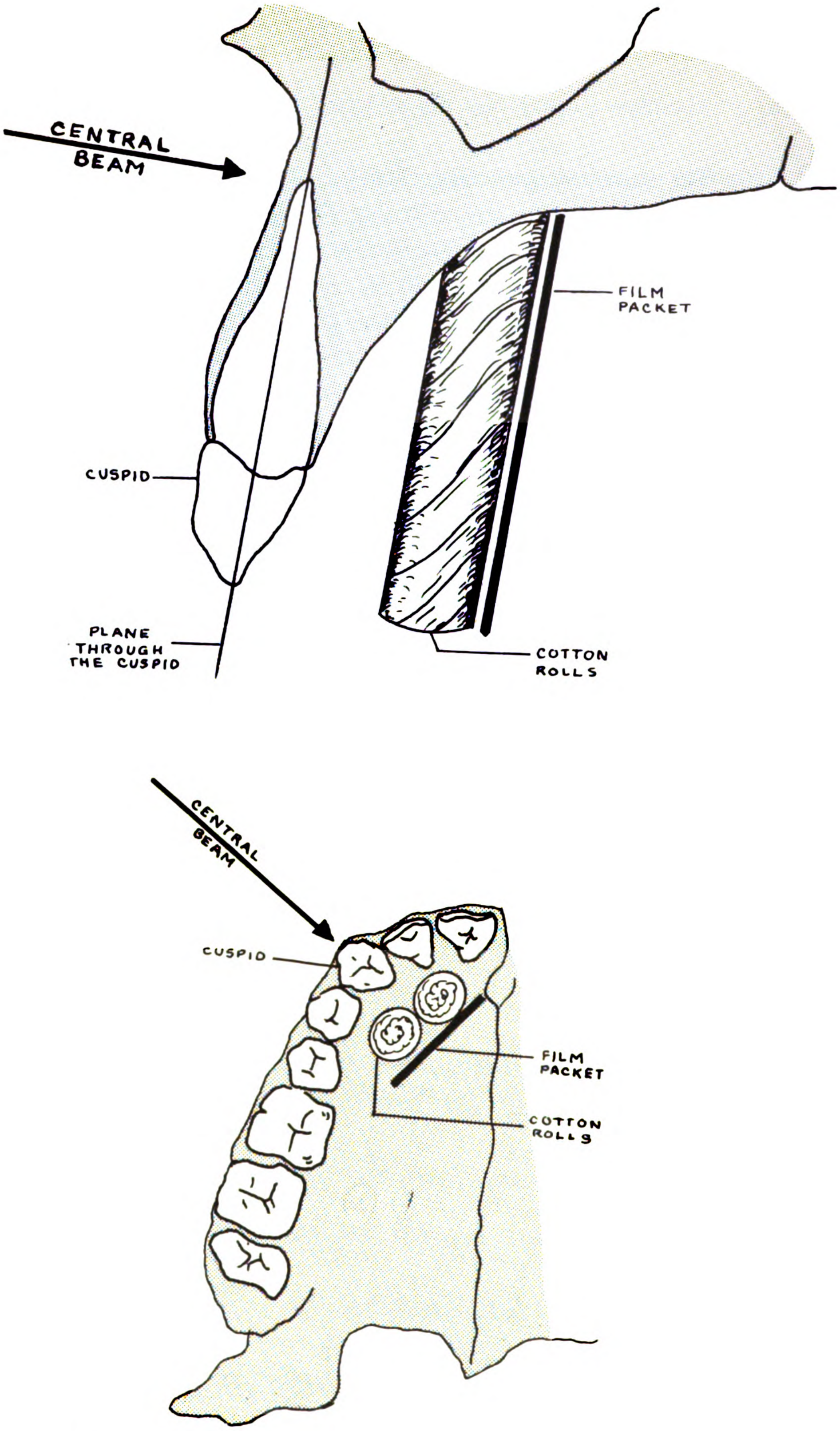


Figure VII -6 -- Cuspid Projection (Maxilla).

(1) Area of Examination

(a) Entire cuspid with margin over apex

(b) Distal portion of adjacent lateral. In some cases the entire lateral and possibly distal portion of central Mesial portion of adjacent first bicuspid.

(c) Usually portions of the nasal and maxillary sinus appear on this projection.

(d) See Figure VII-6 and Appendix A, Plate 6-B.

(2) Film Size

(a) 2.4 x 4 centimeters

(b) 3.2 x 4.1 centimeters useful in revealing gross impactions

(3) Film Exposure

(a) Refer to exposure guides and equipment manufacturer's recommendations

(b) See Technical Factors, Chapter IV

(4) Film Placement

(a) Film centered on lingual surface of cuspid and positioned parallel to the plane of the cuspid.

(5) Film Retention

(a) Two No. 3 cotton rolls on surface of film (tube side)

(b) Patient's thumb

(6) Angulation and Central Beam

(a) Vertical and horizontal angle perpendicular to film

(b) Central beam (CB) directed through the middle of the cuspid. The height of contour on the labial surface is usually a good guide for the mid point.

c. Maxillary First and Second Bicuspid
See Figure VII-7 and Appendix A, Plate 6-C.

Radiographing the bicuspids introduces some considerations in addition to those involving the anterior teeth. The bicuspids are set back further in the oral vault and somewhat less easily accessible with fingers and cotton rolls. But even more important in order to project properly the bicuspids, we should take advantage of the maximum vertical dimension in the mouth. This necessarily means moving further away from the teeth. For this purpose the film should be placed somewhere along the median line or preferably slightly beyond it. (Refer to Figure VII-7.) Remember that the film is so placed that it forms a plane parallel to the visualized plane through the bicuspids. The first and second bicuspids are combined as a unit on this projection since both teeth can be neatly radiographed without compromising any requirements for accurate technique.

The radiograph of the maxillary bicuspids should show, in addition to the entire first and second bicuspid, the distal portion of the adjacent cuspid, the first molar and most of the second molar. Portions of the maxillary sinus will usually also appear on this radiograph. (Refer to Figure VII-7 and Appendix A, Plate 6-C.)

The geometric considerations presented by the maxillary bicuspids make the use of a film holding device very desirable. The film holder allows for an easier and more flexible placement of the film packet once the technician has become adept at manipulating this device. Some dexterity is involved in the use of film holders so it is imperative to acquire some skill in placing this device before using it on a patient. Practice with a dry skull is excellent preparation for this purpose. Lacking the ideal subject even a small-necked bottle may serve as a subject in acquiring some skill in manipulating the film holder.

A number of film holding devices have been developed and most of them are available through dental equipment suppliers. One of the simplest and perhaps most fool-proof is a hemostat equipped with a rubber bite-block and metal backing. Many technicians with extensive experience have adopted this as a basic holding device where accuracy and minimal gag response are major considerations.

The larger film (3.2 x 4.1 cm) is used for this radiograph with a metal backing placed in contact with the film packet on the side away from the X-ray tube. The film and metal backing are then clamped securely into the film holder. With this arrangement it is a simple matter to rotate the clamp in the rubber bite-block so that the inclination of the film will match the plane of the tooth being radiographed. The film is placed into the mouth with the plane of the film parallel to the occlusal and then rotated so that the bite-block comes into a normal contact with the incisal edges of the anterior teeth. The teeth serve as a fulcrum point while the upper edge of the film packet is brought lightly into contact with the palate. The patient is then instructed to bite gently but securely upon the rubber bite-block. The patient should be able to retain the film and film holder in this position while the technician ascertains the accuracy of the film placement and simultaneously aligns the X-ray beam and makes the exposure. Any adjustment of the inclination of the film holder in the bite-block must be made outside the mouth. The student will readily learn to evaluate the dental characteristics of his patient and make these adjustments almost automatically. However, even the most experienced technician will make several adjustments in the exceptional situations to insure a good result. A trial and error technique cannot be condoned in radiography where humans are concerned.

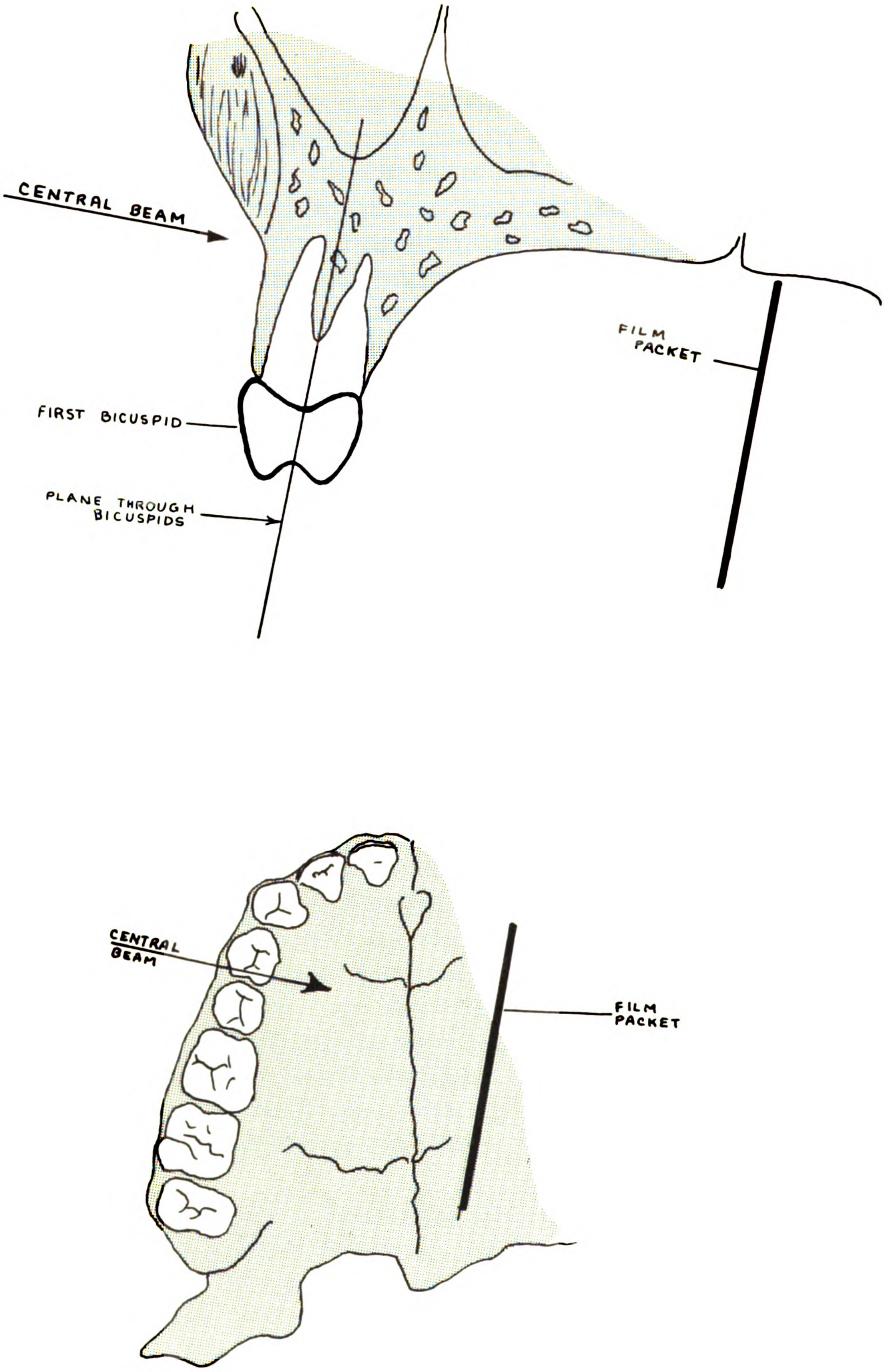


Figure VII -7 -- Bicuspid Projection (Maxilla).

(1) Area of Examination

  (a) Entire first and second bicuspids with margin over apex

  (b) Distal portion of adjacent cuspid

  (c) See Figure VII-7 and Appendix A, Plate 6-C

(2) Film Size

  (a) 3.2 x 4.1 centimeters used horizontally usually

  (b) 3.2 x 4.1 centimeters used vertically for some special situations and probably for most children under seven years of age.

  (c) 2.4 x 4 centimeters used vertically and partially folded for children five years of age and younger. Film retention would probably be with cotton rolls and patient's thumb.

(3) Film Exposure

  (a) Refer to exposure guides and equipment manufacturer's recommendations

  (b) See Technical Factors, Chapter IV.

(4) Film Placement

  (a) Plane of film is placed parallel to plane of bicuspids

  (b) Upper edge of film approximately along median suture line

(5) Film Retention

Film holder with metal backing

(6) Angulation and Central Beam

  (a) Vertical and horizontal angle perpendicular to film

  (b) Central Beam directed through proximal surface of first and second bicuspids

d. Maxillary First and Second Molars

See Figure VII-8 and Appendix A, Plate 6-D.

The procedure for radiographing the maxillary molars follows the pattern outlined for the bicuspids. The film is aligned so that it lies parallel to the plane of the molars and placed farther back into the mouth than for the bicuspid radiograph. The central beam is directed through the proximal surface of the first and second molars. The film should also be placed somewhat farther away from the teeth to allow for complete projection of the apices onto the film. Keeping the film well away from the molars and utilizing the maximum vertical dimension will facilitate projecting the lingual root onto the film. The lingual root is usually longer and for this reason often presents a problem for the less experienced technician.

The first and second molars are considered the primary area of concern on this radiograph although the third molar is included in most cases. Because of some anatomical differences and the positioning of the third molar it is considered useful to include a separate radiograph of this tooth in which it is the primary area of focus. Therefore, projecting the third molar will be covered under a separate heading.

The radiograph of the maxillary molars should show: the distal half of the adjacent second bicuspid (in some mouths this may include portions of the first bicuspid), the first and second molars in their entirety, the third molar where it is completely erupted in normal position, the floor of the maxillary sinus and the tuberosity.

The film holder is ideally suited for working in the molar area but since the distal edge of the film is well back in the mouth it is more apt to aggravate a gag response. The student should be particularly cautious in this area and fortify himself with the assurance that can come only from adequate preparation and practice.

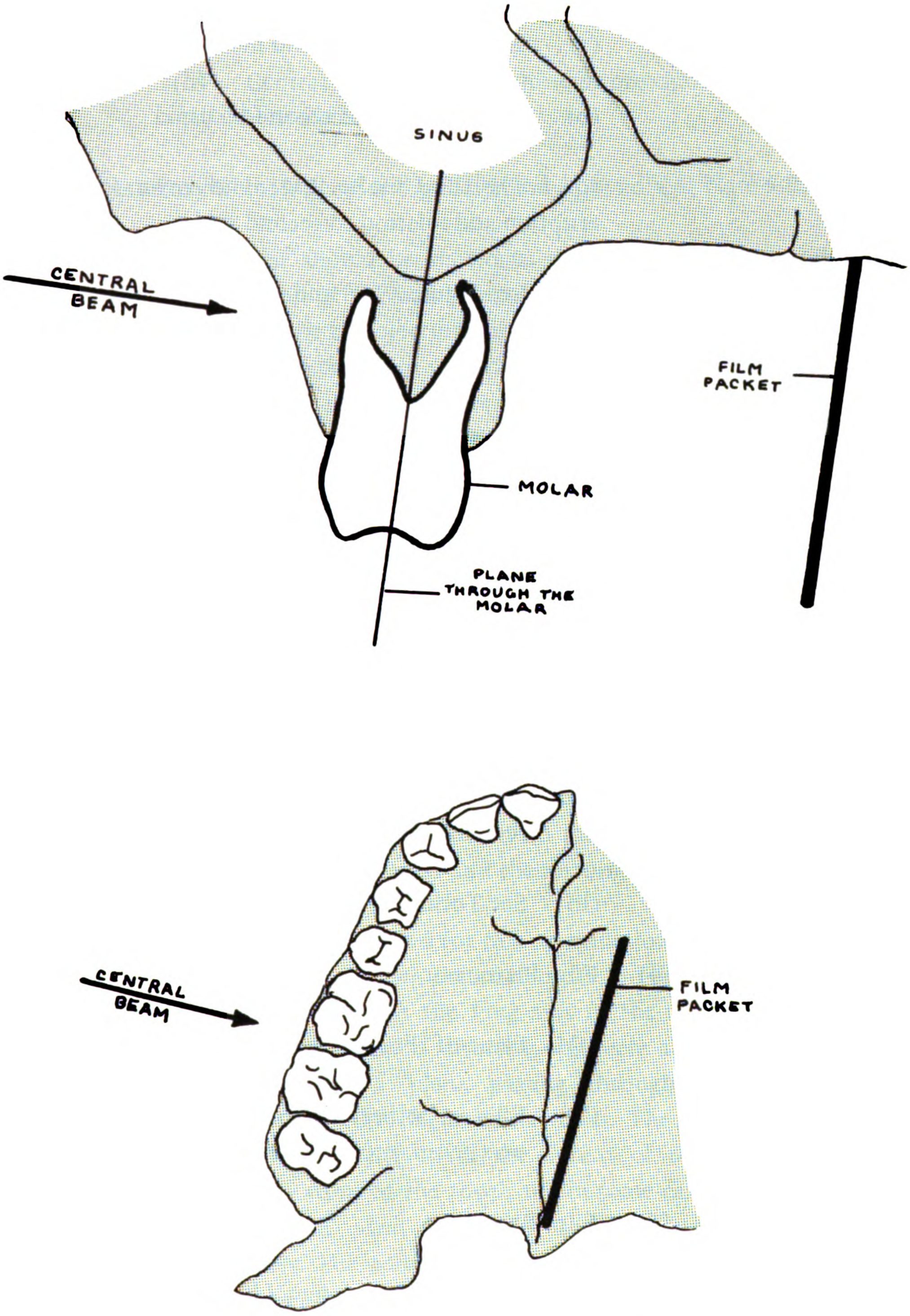


Figure VII -8 -- Molar projection (Maxilla).

(1) Area of Examination

  (a) Entire first and second molars with margin over apex

  (b) Distal portion of second bicuspid

  (c) The third molar. Extent of coverage depends on extent of eruption and relation to second molar.

  (d) See Figure VII-8 and Appendix A, Plate 6-D

(2) Film Size

  (a) 3.2 x 4.1 centimeters used horizontally

  (b) 3.2 x 4.1 centimeters used vertically for some special conditions

  (c) 3.2 x 4.1 centimeters used vertically with a portion of film folded in some children's techniques.

(3) Film Exposure

  (a) Refer to exposure guides and equipment manufacturer's recommendations

  (b) See Technical Factors, Chapter IV

(4) Film Placement

  (a) Plane of film parallel to plane of molars

  (b) Film at farthest distance from molars which still allows use of maximum vertical dimension in mouth.

(5) Film Retention

  (a) Film holder with metal backing support

(6) Angulation and Central Beam

   (a) Vertical and horizontal angle perpendicular to film

   (b) Central beam directed through proximal surface of first and second molars

e. Maxillary Third Molar See Fig. VII-9 and Appendix A, Plate 6-E,F,G, and H.

The third molar should be shown to whatever extent is possible on the normal projection of the maxillary molar radiograph. This should then be supplemented with a projection directed primarily at revealing the entire third molar. Since the third molar is often unerupted or partially erupted, frequently rotated and sometimes obscuring supernumerary teeth, it has been found desirable to include routinely a distal oblique projection when examining this area.

The distal oblique is a departure from previous projections in one respect: That is where an oblique view of the third molar is projected rather than its lateral aspect. This is justifiable, however, since its lateral view is shown to some extent in the normal molar radiograph, and the oblique view is supplementary to reveal the special conditions peculiar to this area.

In this radiograph practically everything mesial to the third molar is distorted and of little diagnostic value, so the projection is made with the third molar approximately centered on the film. In this way a clear view may be had of the third molar and the retromolar area.

The film holder is well suited for this examination and is placed somewhat obliquely across the median suture in order to maintain a plane parallel to the oblique plane through the long axis of the third molar. (See Figure VII-9.) The central beam is directed obliquely across the third molar as one would visualize a plane passing through the tooth from the bucco-distal cusp to the linguo-mesial cusp. The horizontal and vertical angle will vary frequently with the extent of eruption and degree of inclination or rotation of the tooth and in some cases it may be necessary to compromise the ideal angulation to avoid superimposition of the coronoid process. The coronoid process will generally be cast mesially but it may even be cast distally rather than have it superimposed on the area of examination.

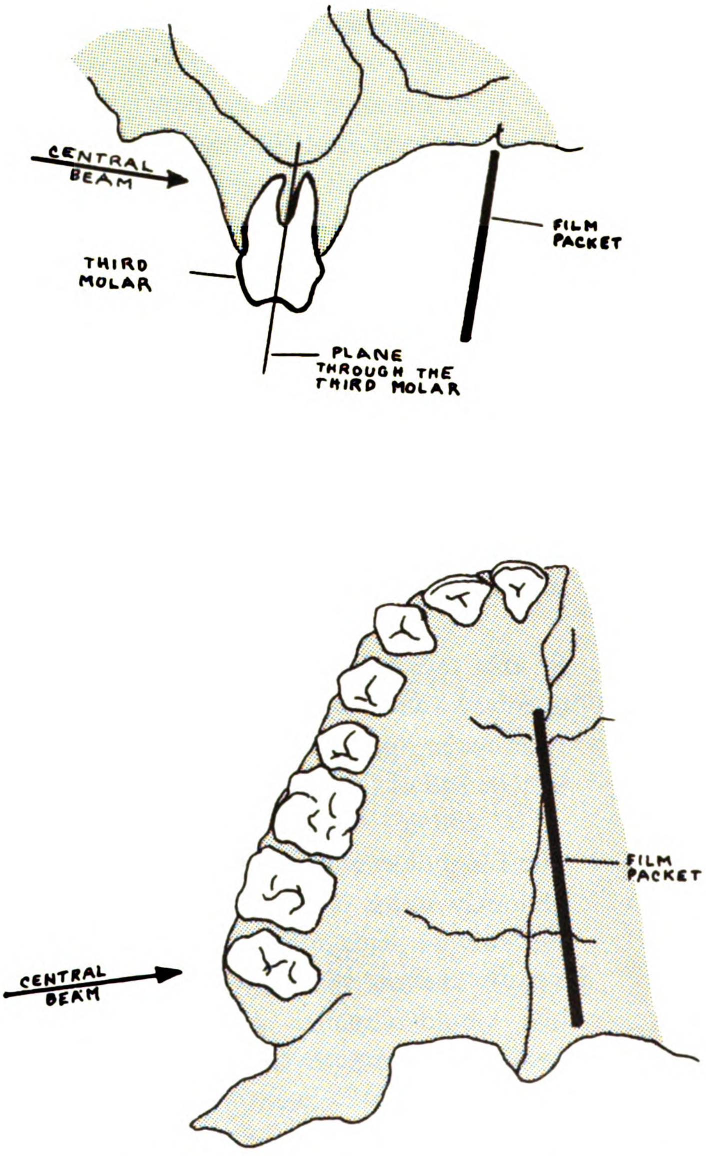


Figure VII -9 -- Molar distal projection (Maxilla).

(1) Area of Examination

  (a) Entire third molar with a margin over the apex

  (b) Disto-molar area, hamular process and portions of coronoid process

  (c) See Figure VII-9 and Appendix A, Plate 6-E, F, G, and H.

(2) Film Size

  (a) 3.2 x 4.1 centimeters used horizontally

  (b) 3.2 x 4.1 centimeters used vertically with a portion folded in some children's techniques.

(3) Film Exposure

  (a) Refer to exposure guides and equipment manufacturer's recommendations.

  (b) See Technical Factors, Chapter IV

(4) Film Placement

  (a) Plane of film parallel to oblique plane through the third molar

  (b) Film at farthest distance from third molar which will still allow use of maximum vertical dimension in mouth

(5) Film Retention

  (a) Film holder with metal backing

(6) Angulation and Central Beam

  (a) Vertical and horizontal angle perpendicular to film

  (b) Central beam directed obliquely through third molar.

6. Periapical Technique for the Mandible

a. Mandibular Central and Lateral Incisors See Figure VII-10 and Appendix A. Plate 7-A.

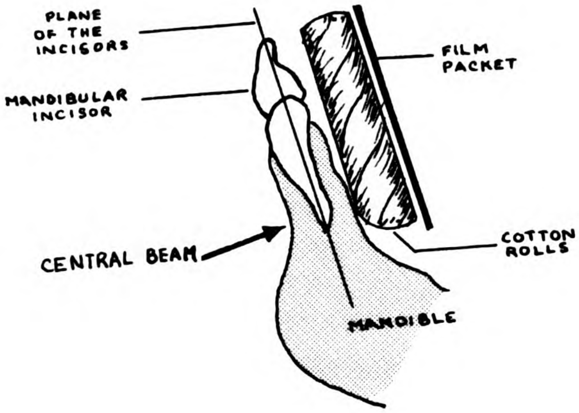
The procedure for radiographing the mandibular central and lateral incisors is similar to that in the maxilla. However, in most individuals the lateral and vertical dimensions will be more restricted. To overcome these restrictions it is necessary to work as far away from the teeth as the tongue will permit. The superior-inferior dimension of the mandible usually presents the greater obstacle for film placement. The film must be placed well back under the tongue and the patient then encouraged to relax the tongue so that the inferior border of the film may drop low enough to allow for a margin of film below the apices of the teeth.

The mandibular central and lateral incisors should be projected so that they appear centered on the film. This will allow for portions or all of the adjacent central and cuspid also to appear on the film. As in the maxillary counterpart of this projection the narrow film is used with two cotton rolls fitted on the long axis of the film. See Figure VII-10. The film and cotton rolls are positioned well back under the tongue and parallel to the plane of the central-lateral incisors. The patient's index finger is placed across the back of the film for retention. In order to stabilize the film it is desirable to place a cotton roll upon the superior border of the film and have the patient gently bite onto the cotton roll and secure it in the proper position. This is particularly important to keep the film sufficiently deep in the mouth and to avoid blurring the image due to tongue movement.

Where the hand is used to assist in film retention it will be found that the hand opposite the side being radiographed is best suited for this purpose. It must be emphasized that the technician never uses his hands for film retention during any exposure. In those few situations where the patient is unable to use his hands a film holding device should be used or, if necessary, the assistance of a relative or friend may be considered.

With the plane of the film parallel to the plane of the central-lateral incisors, the central beam is directed perpendicular to these planes and through the proximal surface of the central-lateral. Where good alignment of the teeth is present this contact should be shown open on the radiograph.

In visualizing the long axis of the incisors it should be noted that an anatomical condition similar to that in the maxillary incisors prevails. Refer to Figure VII-4 for a false plane which results from misjudging the long axis of these teeth. If the technician is consistently cutting-off the apices or elongating the incisor image, it would be useful to review the anatomy of the mandible and its dentition.



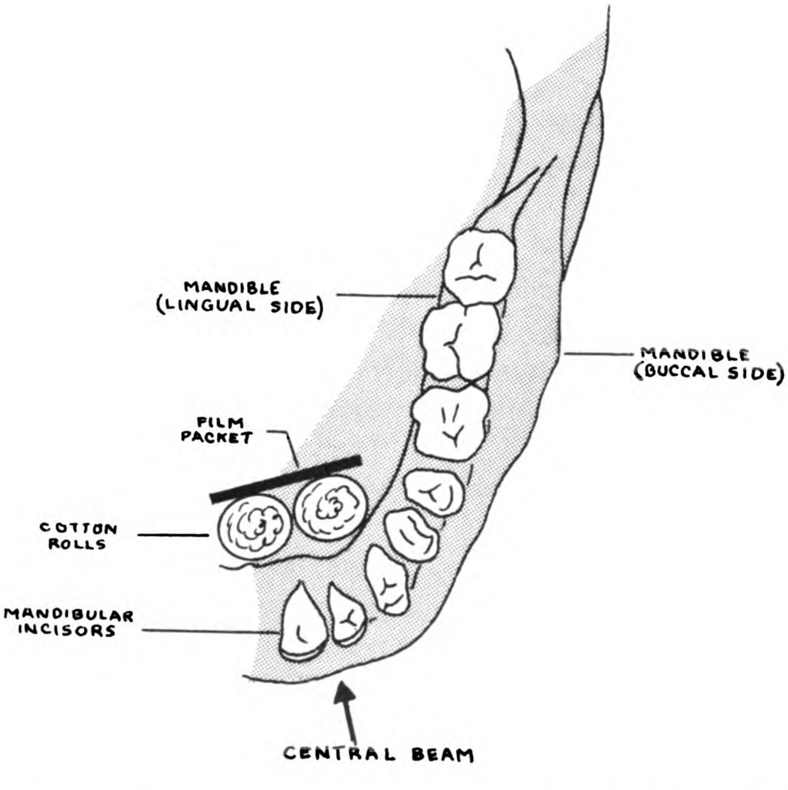


Figure VII -10-- Central-lateral incisor projection (Mandible).

(1) Area of Examination

(a) Entire central and lateral incisors with margin over apices.

(b) Portions of adjacent central incisor and cuspid. In some cases all of these adjacent teeth will show.

(c) Contacts between centrals and lateral will be open. Overlapping of contacts will occur where teeth are in poor alignment.

(d) See Figure VII-10 and Appendix A, Plate 7-A.

(2) Film Size

2.4 x 4.0 centimeters.

(3) Film Placement

Film centered on lingual surface, placed well back under tongue and parallel to the plane formed by the central-lateral incisors.

(4) Film Retention

(a) Two No. 3 cotton rolls on surface of film (tube side). See Figure VII-10.

(b) Patient's index finger along back of film packet.

(c) One cotton roll placed on incisal border of film. Patient bites on this cotton roll to secure film.

(5) Angulation and Central Beam

(a) Vertical and horizontal angle perpendicular to film packet.

(b) Central beam directed through proximal surface of central and lateral. Where overlapping of contacts occurs, visualize normal contact and project accordingly.

b. Mandibular Cuspid

See Figure VII-11 and Appendix A, Plate 7-B.

The procedure for radiographing the mandibular cuspid is similar to that for the mandibular central and lateral incisors. The tongue may be somewhat less of an obstacle in this area but because the cuspid is greater in length it is necessary to place the film well down into the soft tissue in the floor of the mouth. The cuspid should be projected onto the center of the film. This will result in portions or all of the adjacent lateral incisor and bicuspid being shown on this radiograph. The contact on both sides of the cuspid usually show open. Overlapping of the adjacent teeth may close either or both contacts but the primary concern is to show the cuspid in its true relationship to the other dentition even though it may be rotated in its socket.

Film retention follows the same sequence outlined for the central-lateral incisors.

The central beam is projected perpendicular to the plane of the film packet and through the middle of the cuspid. In the normal case the middle of the cuspid as viewed from the X-ray tube will be the height of contour on the labial side of the cuspid.

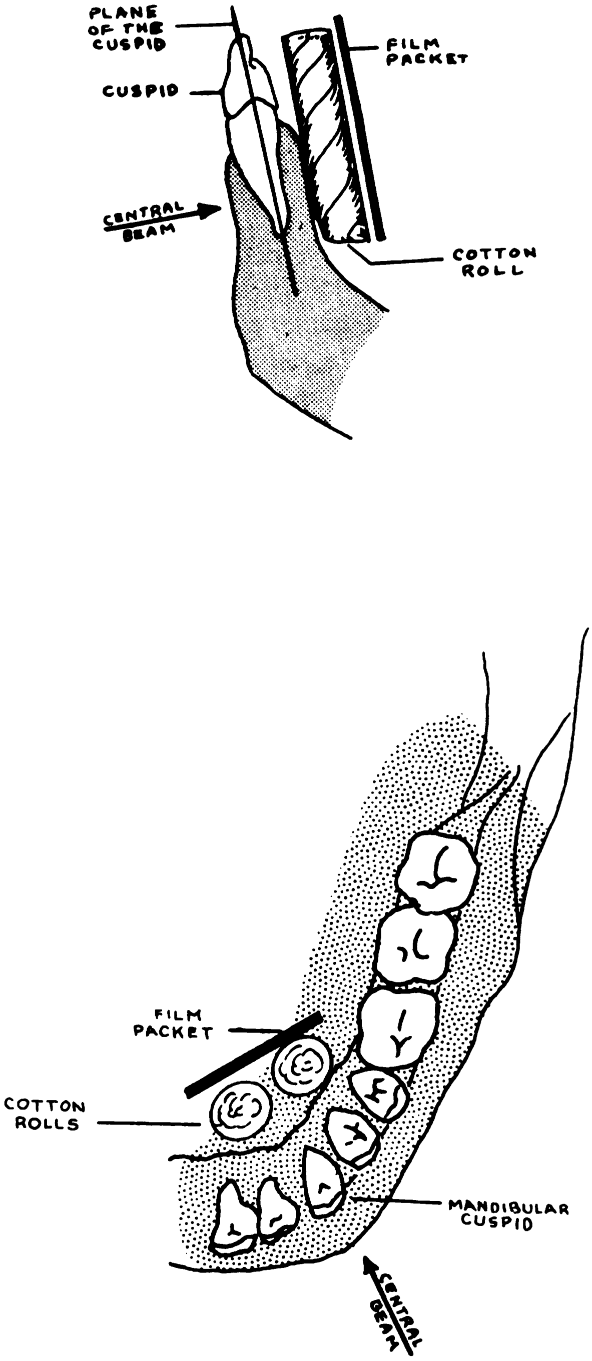


Figure VII -11-- Cuspid projection (Mandible).

(1) Area of Examination

(a) Entire mandibular cuspid with margin under apex.

(b) Portions or all of adjacent lateral and bicuspid.

(c) See Figure VII-11 and Appendix A, Plate 7-B.

(2) Film Size

2.4 x 4.0 centimeters.

(3) Film Exposure

(a) Refer to exposure guides and equipment manufacturer's recommendations.

(b) See Technical Factors, Chapter IV.

(4) Film Placement

(a) Film centered on lingual surface of cuspid and positioned parallel to plane of cuspid.

(b) Inferior border of film packet placed under tongue and well down into soft tissue on floor of mouth.

(5) Film Retention

(a) Two No. 3 cotton rolls on surface of film.

(b) Patient's index finger along back of film.

(c) One cotton roll placed on incisal border of film. Patient bites on cotton roll to secure film packet.

(6) Angulation and Central Beam

(a) Vertical and horizontal angle perpendicular to film.

(b) Central beam through height of contour on labial surface of cuspid.

c. Mandibular First and Second Bicuspid

See Figure VII-12 and Appendix A, Plate 7-C.

The procedure for radiographing the bicuspids is similar to that outlined for the cuspid and incisors. The narrow film (2.4 x 4.0 centimeters) is used with its longer dimension placed vertically in the mouth. Securing adequate depth without causing undue discomfort is a major difficulty for the inexperienced technician. This difficulty is almost invariably associated with a tendency for the technician to lose control of the film and allow the inferior edge to gouge into the mandibular arch. It is important to find the proper depth in the soft tissue on the floor of the mouth and maintain the film immobile not only until the patient's index finger takes over control but also until the patient is biting into the cotton roll on the occlusal border of the film packet. At this point the packet should be sufficiently well stabilized so it will not drift into an uncomfortable position.

The radiograph of the mandibular bicuspid should show, in addition to the first and second bicuspid, at least the distal contact of the adjacent cuspid and a portion of the adjacent first molar. Refer to Figure VII-11 and Appendix A, Plate 7-C.

The mental foramen frequently appears near the apical end of the bicuspids and may even fall on an apex in such a manner as to suggest pathological involvement of the apices. If this becomes a serious consideration it may usually be resolved by a supplemetary projection in which the radiolucents of the foramen may be shifted mesially or distally so as not to lie on the apex of the tooth.

The film packet is fitted with two No. 3 cotton rolls along its long axis and placed against the lingual surface of the bicuspids with the inferior border well down into the soft tissue under the tongue. A third cotton roll is placed on the superior border of the film to allow the patient to bite gently but firmly after supporting the back of the film with his index finger.

The central beam is directed through the proximal surfaces of the bicuspids at a point near their apices.

The narrow film is used as described above for normal projections but the wider film may also be used very effectively where a wider lateral view is desirable, such as to reveal a cyst involving the bicuspids and molar, or where some pathological involvement extends mesially beyond the bicuspids.

Normally the cotton roll and index finger serve for film retention but for some special situations one should not overlook the use of a hemostat and bite-block or simply the use of a slotted wooden or acrylic bite-block.

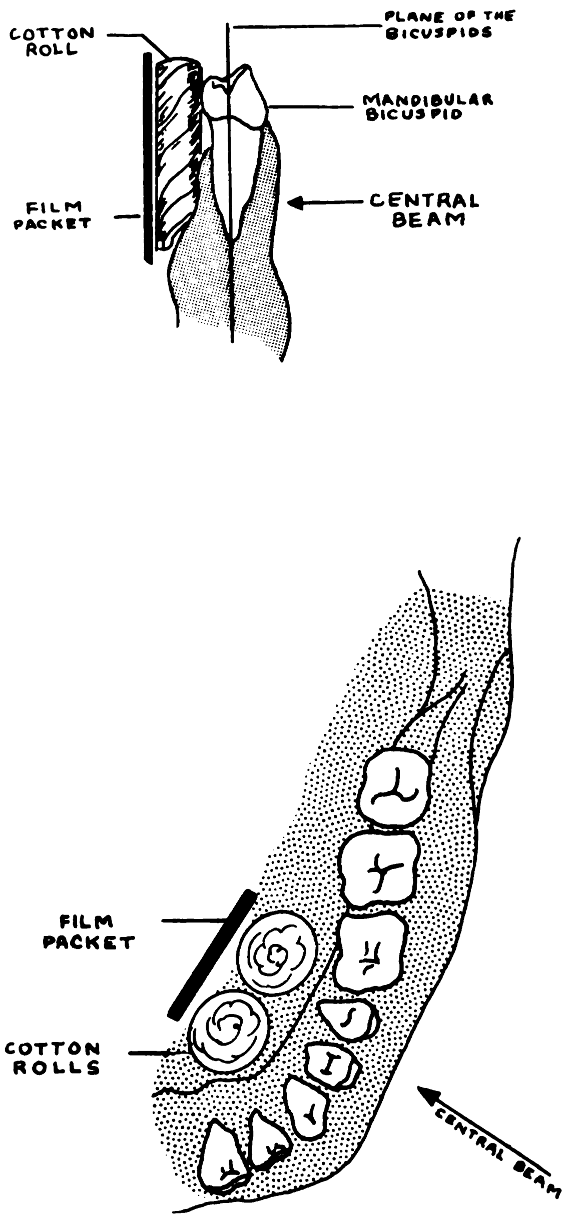


Figure VII -12-- Bicuspid projection (Mandible).

(1) Area of Examination

(a) Entire first and second bicuspids with margin under apices.

(b) Portions of adjacent cuspid and molar.

(c) Probably the mental foramen.

(d) Where good dental alignment is present all contacts will be shown open.

(e) See Figure VII-12 and Appendix A, Plate 7-C.

(2) Film Size

(a) 2.4 x 4.0 centimeters used vertically in the normal examination.

(b) 3.2 x 4.1 centimeters used vertically for some special examinations where a greater lateral aspect of the area is required.

(3) Film Exposure

(a) Refer to exposure guides and equipment manufacturer's recommendations.

(b) See Technical Factors, Chapter IV.

(4) Film Placement

(a) Film packet with two cotton rolls is placed on the lingual surface of bicuspids and well down into the soft tissue under the tongue.

(b) Plane of film packet is parallel to plane of bicuspids.

(5) Film Retention

    (a) Two No. 3 cotton rolls between bicuspids and tube side of film packet.

    (b) Patient's index finger to support film packet.

    (c) One cotton roll on occlusal border of film packet to stabilize and maintain proper depth.

(6) Angulation and Central Beam

    (a) Vertical and horizontal angle perpendicular to film.

    (b) CB thru proximal surfaces of bicuspids.

d. Mandibular First and Second Molars
See Figure VII-13 and Appendix A, Plate 7-D.

The first and second molars present conditions which approach the geometrically ideal for radiographic projection. The molars lie in a plane along the dental ridge where it is possible to place the film not only parallel to the plane of the teeth but in the closest proximity.

The wider film packet (3.2 x 4.1 centimeters) should be used horizontally wherever the conformation of the mouth will permit. However, it is possible to cover the two molars using a vertical placement. The need for using the wider film horizontally occurs more frequently because either the molars are so large or the distal root on the second molar is not included on a vertical placement of the film. Also for surgical and orthodontic considerations it is desirable to show more than the mesial contact of the third molar. With a horizontal film placement most of the third molar may be shown and in many cases it may be shown entirely.

The film packet should be placed flat against the lingual surface of the molars and maintained firmly in a parallel plane without the use of cotton rolls or any device to keep the film away from the teeth. As a matter of fact, with these conditions prevailing it would be undesirable to keep the film away from teeth.

Retention of the film packet is accomplished with the index finger placed diagonally across the back of the film and one cotton roll placed on the occlusal border of the film. The patient bites upon the cotton roll to complete the retention.

The lower distal corner of the film packet will necessarily be well into the soft tissue of the lingual reflex so the placement should be approached cautiously to avoid aggravating a gag response.

A good parallel relationship exists almost naturally between the plane of the film and the plane of the first and second molar so it remains only to project the central beam perpendicular to one of these planes. The central beam should be visualized as entering at the proximal surfaces of the molars.

This radiograph should show a distal portion of the adjacent second bicuspid, the entire first and second molars, and a portion or all of the third molar. Where good dental alignment is present all of the contacts will be shown open. A portion of the mandibular canal frequently appears under the apices of these teeth.

Although it is desirable to show as much of the third molar as is practicable on this radiograph, a supplementary view is considered desirable and will be covered separately.

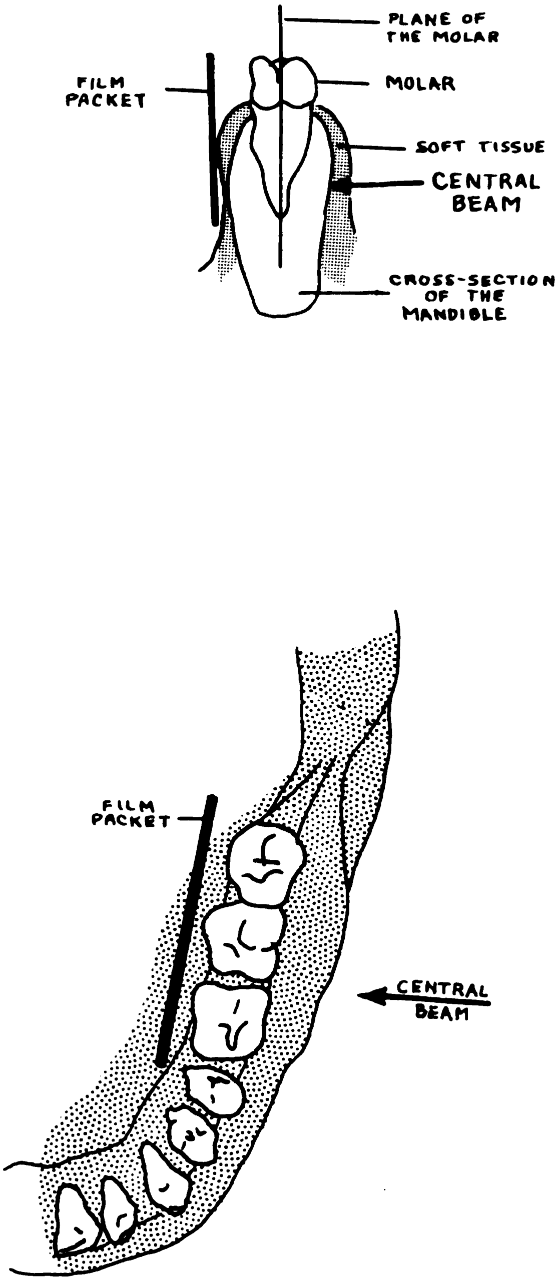


Figure VII -13-- Molar projection (Mandible).

(1) Area of Examination

  (a) Entire first and second molars with margin under apices

  (b) Distal portion of adjacent second bicuspid

  (c) Portion or all of adjacent third molar

  (d) See Figure VII-13 and Appendix A, Plate 7-D

(2) Film Size

3.2 x 4.1 centimeters used horizontally or vertically as conditions dictate

(3) Film Exposure

  (a) Refer to exposure guides and equipment manufacturer's recommendations

  (b) See Technical Factors, Chapter IV

(4) Film Placement

  (a) Plane of film parallel to plane of molars, and in contact with lingual surface of molars and soft tissue

  (b) Film must be maintained low enough into the soft tissue adjacent to the tongue to insure showing a margin below the apices of the teeth.

(5) Film Retention

  (a) Patient's index finger diagonally across back of film and one cotton roll on occlusal border of film with patient biting to maintain secure position.

  (b) Film holding devices may give good results in some cases. Their use is left to the discretion of the technician.

6) Angulation and Central Beam

   (a) Vertical and horizontal angle perpendicular to film.

   (b) Central beam directed through proximal surface of first and second molars.

e. Mandibular Third Molar
See Figure VII-14 and Appendix A, Plate 7-E and F.

As previously indicated, the third molar should be shown to whatever extent is practicable on the radiograph of the first and second molar film. The third molar has a number of inherent conditions and problems which make it desirable to consider it separately. Experience dicates that a supplementary radiograph be included as a routine examination of this area. The third molar is frequently impacted and sometimes horizontally. It may even be inverted with the apex extending well up into the ramus. (See Appendix A, Plate 10.) Its proximity to the mandibular canal is also an important consideration where surgery is contemplated.

In many cases, particularly impactions, the third molar is so far back in the mandible that it cannot be shown readily with the ideal lateral projection. For these situations, it is usually possible to use an oblique projection to cast the third molar forward and still maintain a reasonable amount of anatomical accuracy to preserve its diagnostic value. (Refer to Figure VII-14 and Appendix A, Plate 7-E and F.)

The placement of the film packet is essentially the same as for the routine molar projection except that the film is placed farther back along the dental ridge with the distal end of the film angled slightly toward the lingual, so far as the tongue will permit. The film packet should be depressed into the soft tissue or inclined up the ramus as position of the tooth requires.

This radiograph should show the distal portion of the second molar, all of the third molar, the retro-molar triangle, portions of the mandibular canal, and as much of any related pathological involvement as is practical.

The central beam is directed diagonally across the third molar – for example as one might project a line from the bucco-distal cusp to the linguo-mesial cusp.

Where it is impossible to show entirely the third molar and any related pathology a lateral jaw film is a good supplementary consideration. The third intra-oral radiograph should contain better detail than the extra-oral view but what the latter lacks in detail it makes up in extent of coverage. The combination of intra-oral and extra-oral radiographs may supplement each other very nicely in some complex situations.

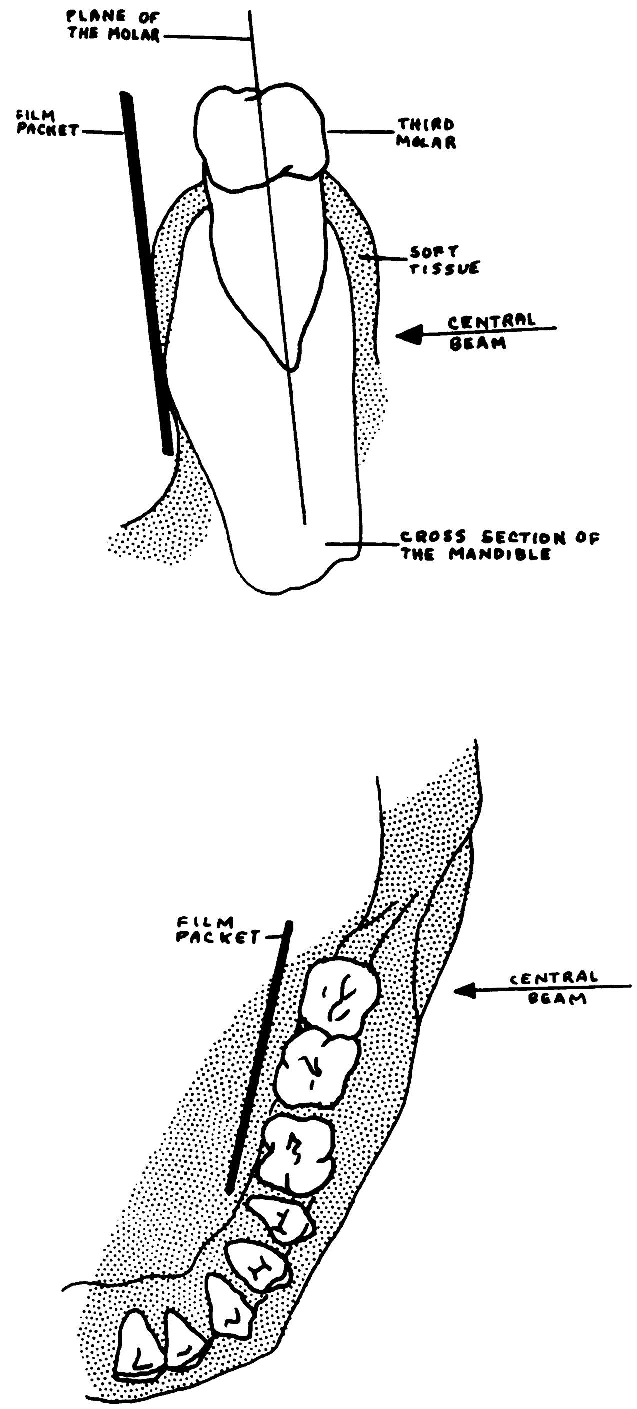


Figure VII -14-- Third Molar projection (Mandible).

(1) Area of Examination

  (a) Portions of second molar and in some cases the distal portion of the first molar

  (b) All of the third molar

  (c) The retro-molar triangle, portions of the mandibular canal

  (d) See Figure VII-14 and Appendix A, Plate 7-E and F.

(2) Film Size

  (a) 3.2 x 4.1 centimeters used horizontally or vertically as required.

(3) Film Exposure

  (a) Refer to exposure guides and equipment manufacturer's recommendations

  (b) See Technical Factors, Chapter IV

(4) Film Placement

  (a) The film packet should be placed laterally to show as much as possible distal to the second molar. If the distal edge of the film packet can be angled slightly toward the lingual it facilitates casting the third molar forward on the film.

  (b) The film packet may be used horizontally or vertically as the conditions require.

(5) Film Retention

  (a) Patient's finger diagonally across back of film packet and one cotton roll on occlusal border with patient biting on cotton roll to maintain secure position.

(b) Film holding devices have a wide variety of applications for this examination.

(6) Angulation and Central Beam

(a) Vertical angle perpendicular to plane of film

(b) Horizontal angle diagonally through third molar

(c) Central beam directed obliquely through third molar

7. Complete Dental Surveys
See Appendix A, Plates 2, 3, 4, and 5.

The preceding techniques form the basis for compiling a complete dental survey. Having mastered each of the basic radiographic areas, the technician is equipped to apply this skill in producing a complete examination of the mouth with precision and consistency. It is recognized that many technicians will introduce some varitions in the procedures outlined here. Minor variations are perhaps natural, not necessarily faulty, so long as the basic principles are followed without compromise. The serious technician will concentrate first on precision, and secondly on standardizing his procedure. Thus, at some later date, perhaps after several years, he can duplicate his earlier radiographic survey of any particular patient.

The basic complete dental survey will vary with the requirements of various dentists and whatever supplementary views are deemed essential. The preceding techniques suggest a minimum of twenty separate radiographs for a complete dental survey. The total number would necessarily be increased where bite-wings or other supplementary films are included on a routine basis. If the radiation factor is a critical consideration the total number could be decreased where the third molar radiograph is an integral part of the first and second molar radiograph. However, as a routine practice, it is believed this reduction would be self defeating in that the number of repeat exposures would be increased due to deficient coverage.

a. Mature Adult Complete Dental Survey
See Appendix A, Plate 2.

This is considered a routine adult dental survey. Bite-wings and several supplementary radiographs are included in this example. The right mandibular molar area was slightly deficient due to a very sensitive gag response, even when the film was used in its narrow dimension a separate radiograph of the second molar was included to insure proper coverage. Other supplementary radiographs were included for periodontal considerations.

b. Young Adult Complete Dental Survey
See Appendix A, Plate 3.

This is a typical examination for a young adult being evaluated for orthodontic correction.

c. Complete Dental Survey for 6 year old child.
See Appendix A, Plate 4.

This is a typical example of a complete dental survey with mixed dentition. The permanent and deciduous dentition should be shown in their entirety. The same basic areas are radiographed as in the adult. The complexity of mixed dentition sometimes requires more supplementary coverage than for permanent dentition in adults but the routine radiographing should be directed at achieving the same composition. There are important reasons for standardizing the procedure to include children and infants. Complete dental surveys for children are frequently related to orthodontic, reconstruction or surgical evaluations and the survey will probably be repeated during the course of several years treatment. For comparative reasons alone it is of great importance to the orthodontist, the surgeon, the general dentist, or any combination of these, to have the survey repeated with the same precision and format each time.

It will be noted that because of limited space in this mouth the molar areas were radiographed using the narrow dimension of the standard film.

d. Complete Dental Survey, 3 yr. old Child.
See Appendix A, Plate 5.

This example illustrates the complete survey for a very young child using the same procedures and format described earlier for older persons. However some modifications of the adult procedure should be noted. First, because of the smaller mouth the larger film is not used horizontally but vertically and a portion of it needs to be folded at the occlusal border to facilitate placement. Secondly, film holding devices are not recommended at this age level because the child is not psychologically or physically ready to accommodate such device with any degree of success. Finally, such an extensive examination should not be undertaken by a novice. It is beyond the scope of these instructions to examine the special considerations in complete dental surveys for infants. Suffice to say that when the technician has sufficient experience to approach every adult survey with complete confidence he is then ready to investigate these special examinations.

8. Occlusal and Topographical Surveys.
See Figures VI-6 and VII-15, 16, 17 and Appendix A, Plates 8 and 9.

The occlusal radiograph is a useful supplementary view and is frequently used as an overall examination of the maxilla or the mandible. Generally it is used to support the findings in periapical examinations such as lesions, supernumeraries, impacted dentition, etc. Whether radiographing the maxilla or the mandible the special occlusal film packet is placed across the occlusal plane. (See Figures VI-6 and VII-15). And the area of interest is projected onto the occlusal plane. In the maxillary occlusal the oblique views are usually the most useful for detail. As the projection approaches the perpendicular the superimposition of intervening tissue detracts from its clarity. At this point it is better to employ the topographical survey which will be discussed later. The oblique views are obviously distorted but much of diagnostic value may be found in these radiographs so long as one does not lose sight of the manner in which it was projected.

Figure VII-15 illustrates a routine occlusal projection of the maxilla. It should be noted that the vertical angle may vary considerably from the one shown, depending upon the area of interest. The 60 degree vertical angle would serve best for an examination of the anterior area of the mouth. Examination of the molar area would require a greater vertical angle that would become more perpendicular to the plane of the film. Also, where the area of interest might be completely to one side of the median line, it would be desirable to shift horizontally to favor that side.

Figure VII-16 illustrates similar examinations for the mandible.

Plate 8, Appendix A, illustrates some special applications of the occlusal survey. Plate 8-A shows an occlusal view, supplementing the periapical view of an unerupted cuspid. Plate 8-B is a similar combination involving supernumerary dentition. Plate 8-C is a typical occlusal showing the labiolingual aspect of impacted cuspids. Plate 8-D shows an occlusal view of orthodontic progress in bringing maxillary cuspids into alignment. Plate 8-E is an occlusal view showing an orthodontic appliance expanding the palate. Plate 9 is a combination of periapical, occlusal and extra-oral radiographs showing an examination of cystic involvment in the mandible.

Topographical surveys are used where greater precision is required such as pre-surgical location of supernumerary dentition. The topographical survey is not intended to replace the occlusal survey, even though it has the following distinct advantages over the conventional occlusal survey: It presents a true cross-sectional view of the palate, it does not distort the object, and objects may be shown in precise location. See Figure VII-17.

The occlusal survey, however has these advantages: It may be executed very quickly and it does not require special equipment; furthermore, because of the acute angular approach to the palate, there is less superimposition of tissue and, when properly executed, it may show considerable detail.

A combination of the factors inherent in the two techniques provides an ideal examination of the palate. It is recommened that the occlusal survey be used in conjunction with the topographical survey by first taking the conventional occlusal to reveal the condition grossly, and then performing the topographical survey to show the precise location and extent of involvement.

Topographical surveys may also be made of the mandible but it has none of the problems inherent in the maxillary view. Refer to Figure VII-16. Following the illustration, a radiograph with the central beam at 90 degrees would produce a good topographical view of the mandible.

For surgical purposes the ideal radiographic examination endeavors to display an anatomical region in three dimensions. Such surveys of the maxilla frequently are concerned with the labiolingual aspect, the buccolingual aspect, and the depth of involvement in the palate. The topographical survey has the distinct advantage of presenting two of these aspects with equal accuracy, namely, the labiolingual and the buccolingual. The third dimension, or vertical aspect, should be used to supplement these and can be secured by periapical type examination or an extraoral view, such as the lateral head radiograph. Wherever possible, the intraoral view is preferable, as it gives a sharper view without the disadvantage of superimposing the opposite side of the maxilla.

The topograhpical survey requires at least one piece, and preferably two pieces, of equipment other than the X-ray generator and film. First, because of the greater densities to be penetrated in approaching the palate from a nearly vertical angle, it is necessary to use an intraoral cassette, particularly in case of a low-kilovoltage generator. The intraoral cassette employs an intensifying screen similar to the type used in typical medical X-ray cassettes. Second, in the vertical approach to the palate there is encountered a tremendous superimposition of tissues and a great increase in secondary radiation. The resulting image is somewhat fused and lacking in sharp detail, although the general form is intact and quite satisfactory for localizing and displaying gross conditions. In order to reduce the fusing of the image, which is largely due to secondary radiation, an intraoral grid is employed. This device, when properly adapted, can reduce the fusing effect and increase the detail. The use of a stationary grid, such as the intraoral grid, means that the resulting image will have the narrow white lines of the grid showing. At first, these lines may appear distracting, but they do not interfere to any extent with the reading of the radiograph. Figure VII-17 illustrates the technique for the maxillary topographical radiograph.

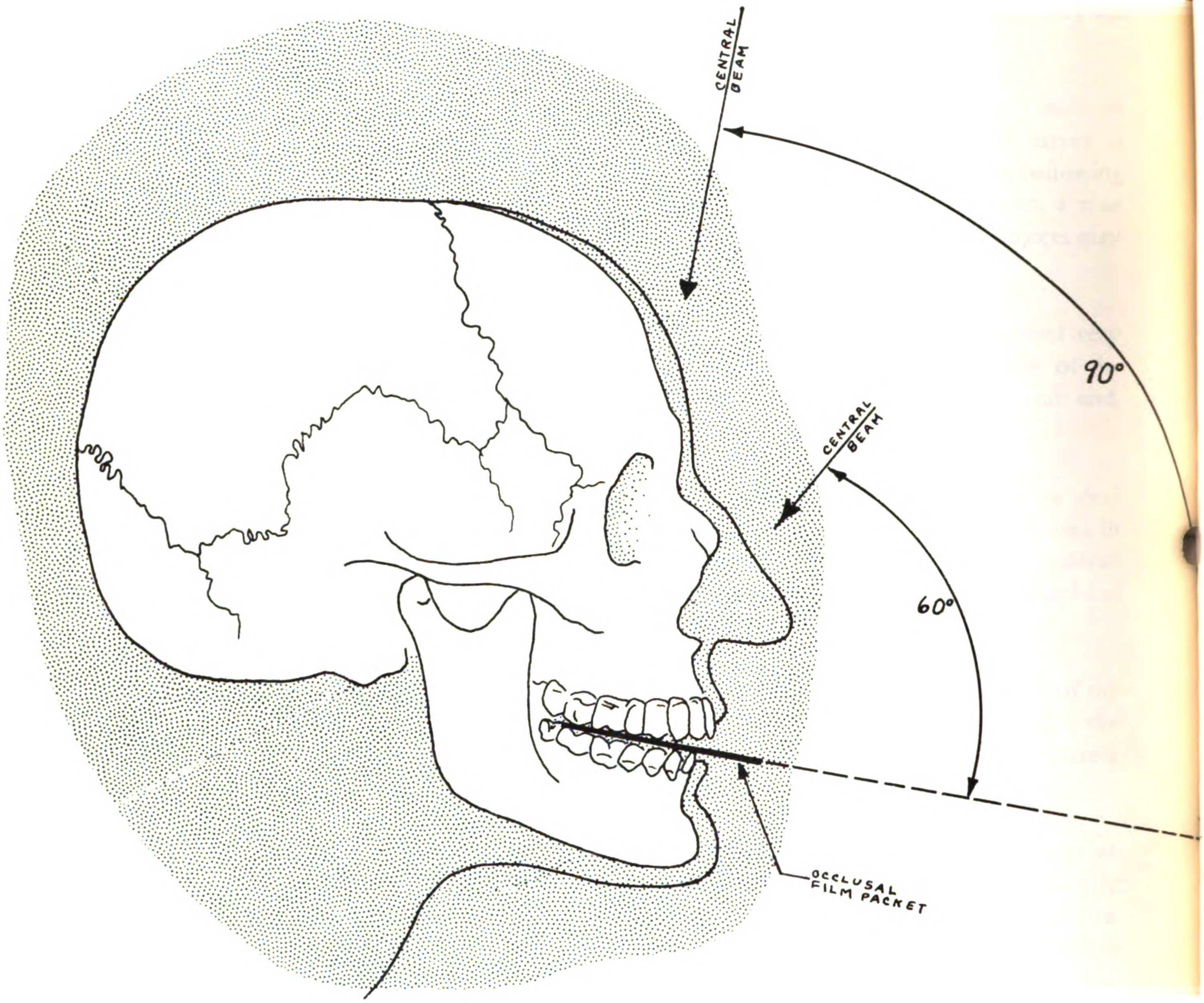


Figure VII -15-- Maxillary occusal projections.

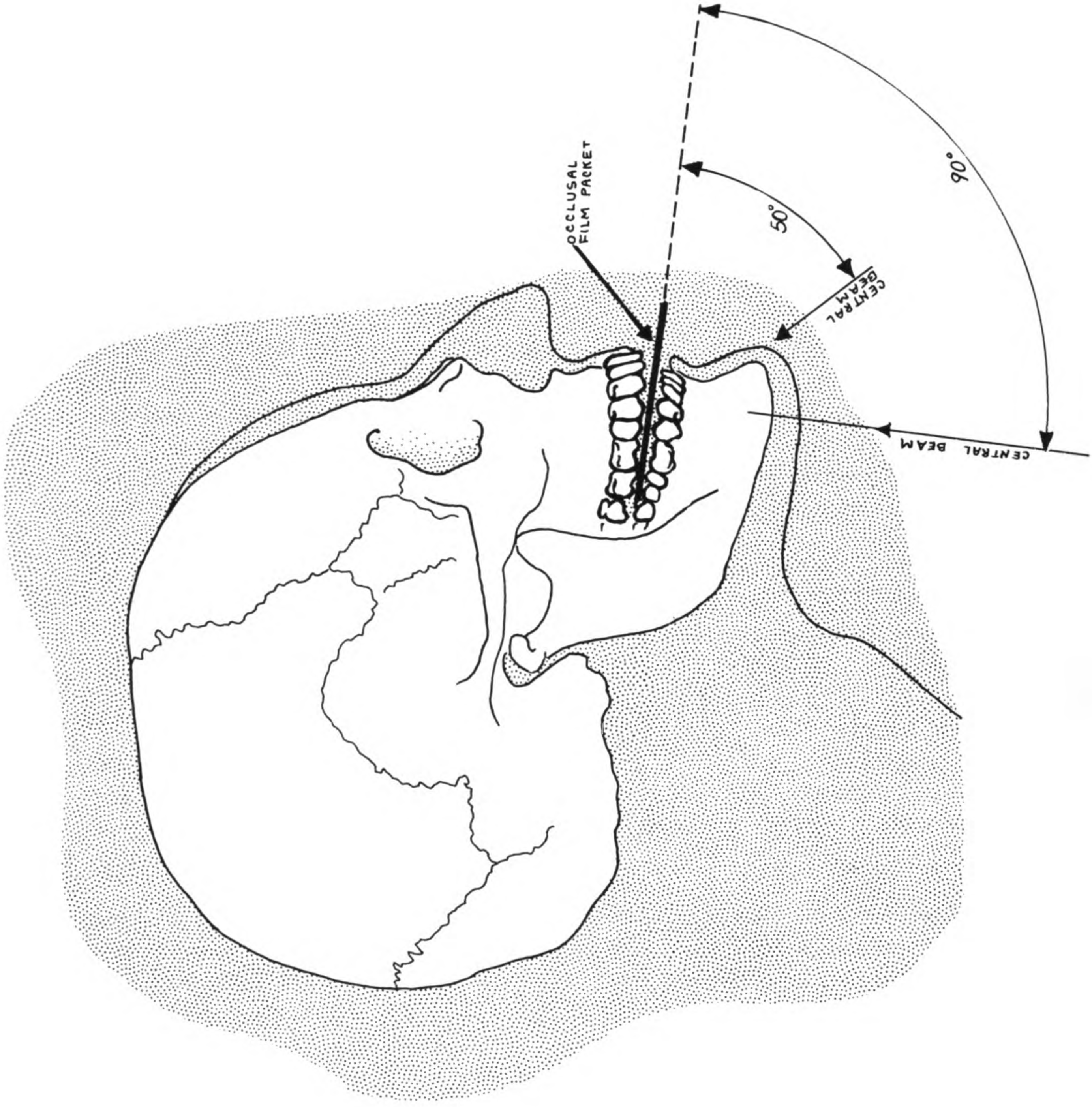


Figure VII - 16-- Mandibular Occlusal Projections

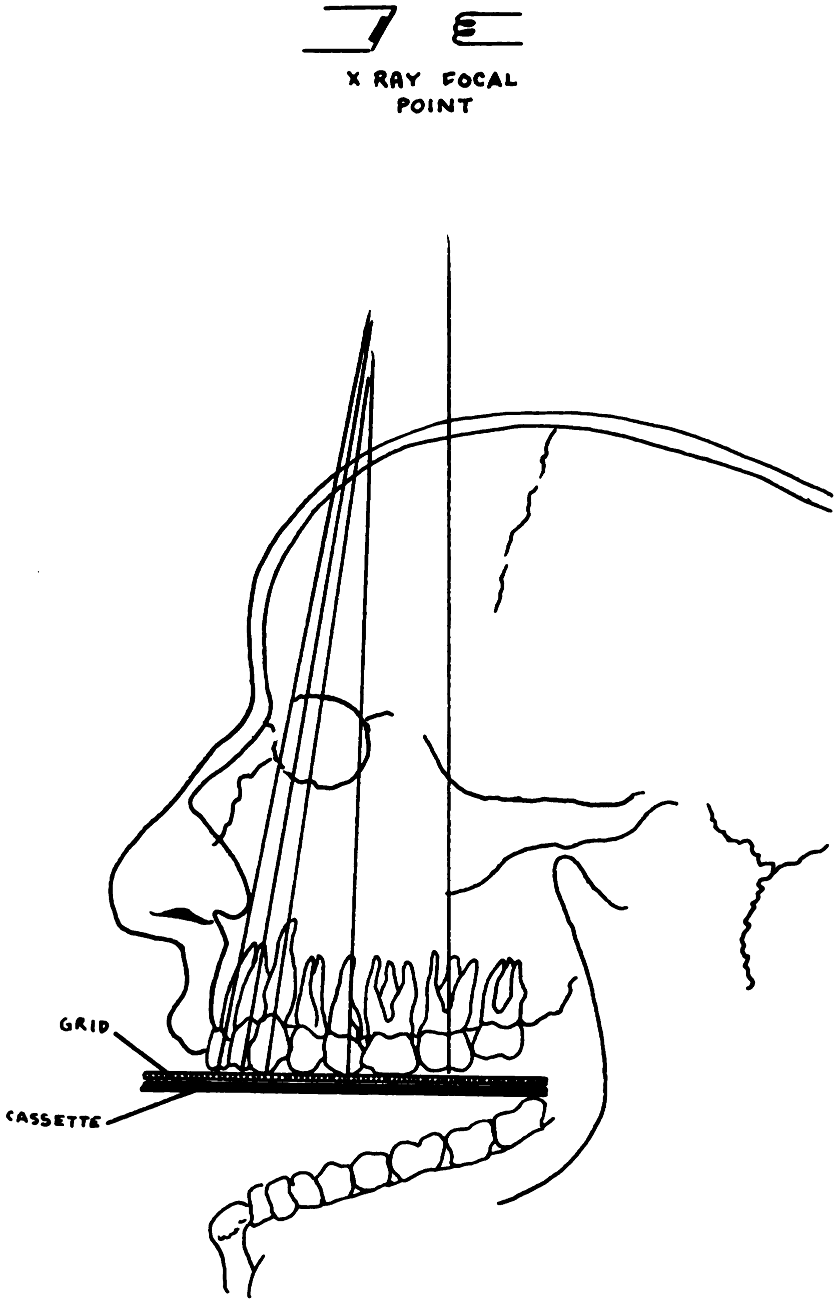


Figure VII -17 -- Topographical survey of maxilla.

B. Cephalometrics.

The value of craniometric analysis has long been established as a most valuable tool for the orthodontist. More recently, the radiographic cephalometer has added to the value of craniometrics by providing a precise technique for recording internal and external measurements. Craniometrics for orthodontic purposes is basically an analysis of successive cephalometric radiographs to establish growth patterns of the face and jaw in relation to the cranial base. See Figure VII-18 for an abbreviated example.

The cephalometer is a precision head holding device used in conjunction with an X-ray source (preferably fine focal spot) and a film-holding cassette. In order to keep the magnification factor minimal, the distance from the anode to mid-sagittal plane is usually 60 or 72 inches, with the film parallel to the sagittal plane and adjacent to the face. It is imperative that all components have the capability for precise calibration. The ideal installation provides for secure locking of all positions following the calibration.

The long anode-film distance necessitates the use of a cassette using flourescent screens. In order to enhance the detail for cephalometric radiographs, it is desirable to use a filtering grid in conjunction with the flourescent cassette. Some installations use a stationary grid. A more expensive and probably preferable grid is the Potter-Bucky diaphragm, in which the film cassette moves across the grid.

Once the equipment has been accurately aligned, the technique for making a cephalometric radiograph is fairly routine. The patient is positioned comfortably in the chair and it is here that the flexibility of the chair proves valuable to allow for comfortable as well as proper positioning.

A good cephalometer is relatively rigid but it is not practical to cinch-up on the sensitive external ear to the point where the patient would be completely immobilized. Therefore, it becomes most important to have such flexibility in the equipment that the patient may be positioned comfortably yet accurately and maintain a fixed position long enough to allow the technician to make the radiograph. The technique of persuasion is an important factor in achieving good results. The cephalometer often appears as a formidable device to children, so setting them at ease is an important factor for a good result.

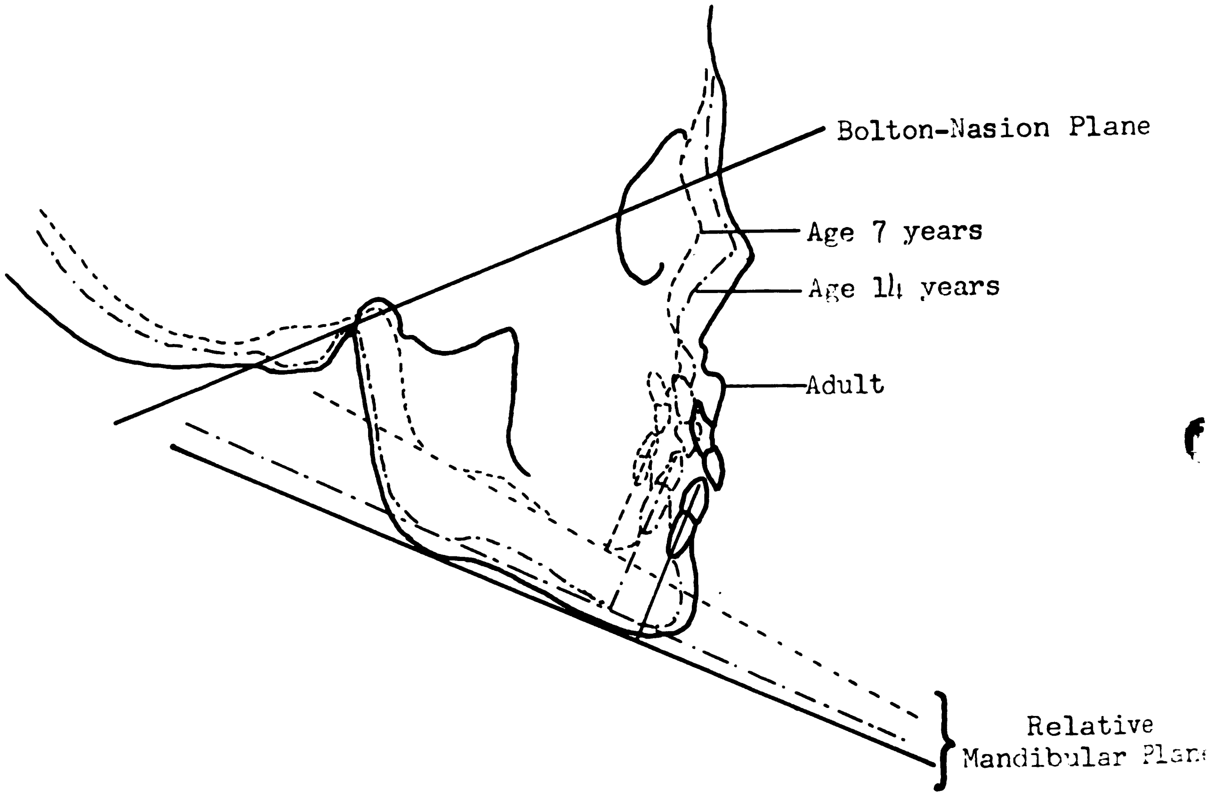


Figure VII -18 -- Craniometric tracings made from cephalometric radiograph.

When the patient is placed with the ear rods in position the frankfort plane should be aligned parallel to the reference base (usually the lower border of the film) and the nasion rest locked into position. Adjust the head so that the sagittal plane rests parallel to the plane of the film. The bite position should be verified to conform to the requisites of the orthodontist and the patient should be reminded to hold the bite-position through completion of the exposure.

A high quality cephalometric installation would have the following types of equipment and characteristics. See Figure VII-19 for an overhead layout diagram:

X-ray generator

a. Rotating anode tube
b. 100 Kilovolt range
c. 30 to 200 Milliampere capacity.

Cephalometer

a. Unit comparable to Appendix C-5
b. Potter-Bucky diaphragm instead of simple cassette holder.

Dental Chair

a. Rotation at least 180 degrees arc.
b. Hydraulic elevator.

The most commonly used cephalometric radiograph is the lateral view; however, frontal views are also frequently employed. The procedure is identical in both cases except for the latter the patient would be rotated 90 degrees and locked into position. See Appendix A, Plates 12 and 13 for cephalometric radiographs.

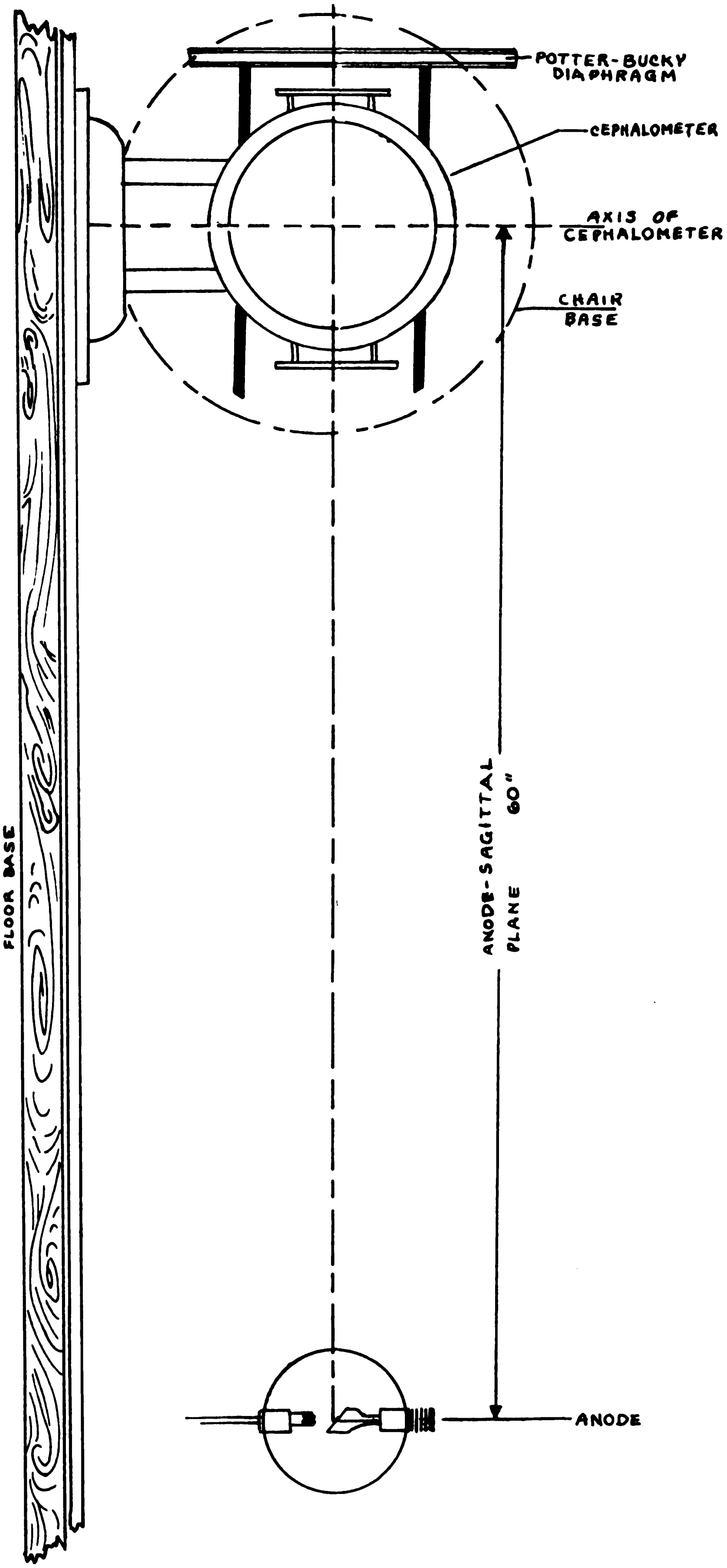


Figure VII -19 -- Overhead layout diagram of cephalometric installation.

DENTAL LABORATORY RADIOGRAPHY

APPENDICES

APPENDIX A:

Radiographic Plates 1 to 14 inclusive.

APPENDIX B:

Reference Publications

APPENDIX C:

Photographs

1. Film Holding Devices
2. Film Holding Assembly
3. X-ray Head, typical dental type unit
4. X-ray Installation
5. Cephalometer

APPENDIX D:

Glossary

APPENDIX E:

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DENTAL LABORATORY RADIOGRAPHY

Appendix A

RADIOGRAPHIC PLATES

Plate
No.

1. Bite-Wing Surveys
2. Complete Dental Survey-Mature Adult
3. Complete Dental Survey-Young Adult
4. Complete Dental Survey-6 yr. Old
5. Complete Dental Survey-3 yr. Old
6. Periapical Survey-Maxilla-Each Area Separately Delineated
7. Periapical Survey-Mandible-Each Area Separately Delineated
8. Occlusal Survey-Maxilla
9. Occlusal Survey-Mandible
10. Lateral Jaw Survey
11. Lateral Head Survey, Dental
12. Cephalometric
13. Cephalometric
14. Effect of Static Electricity

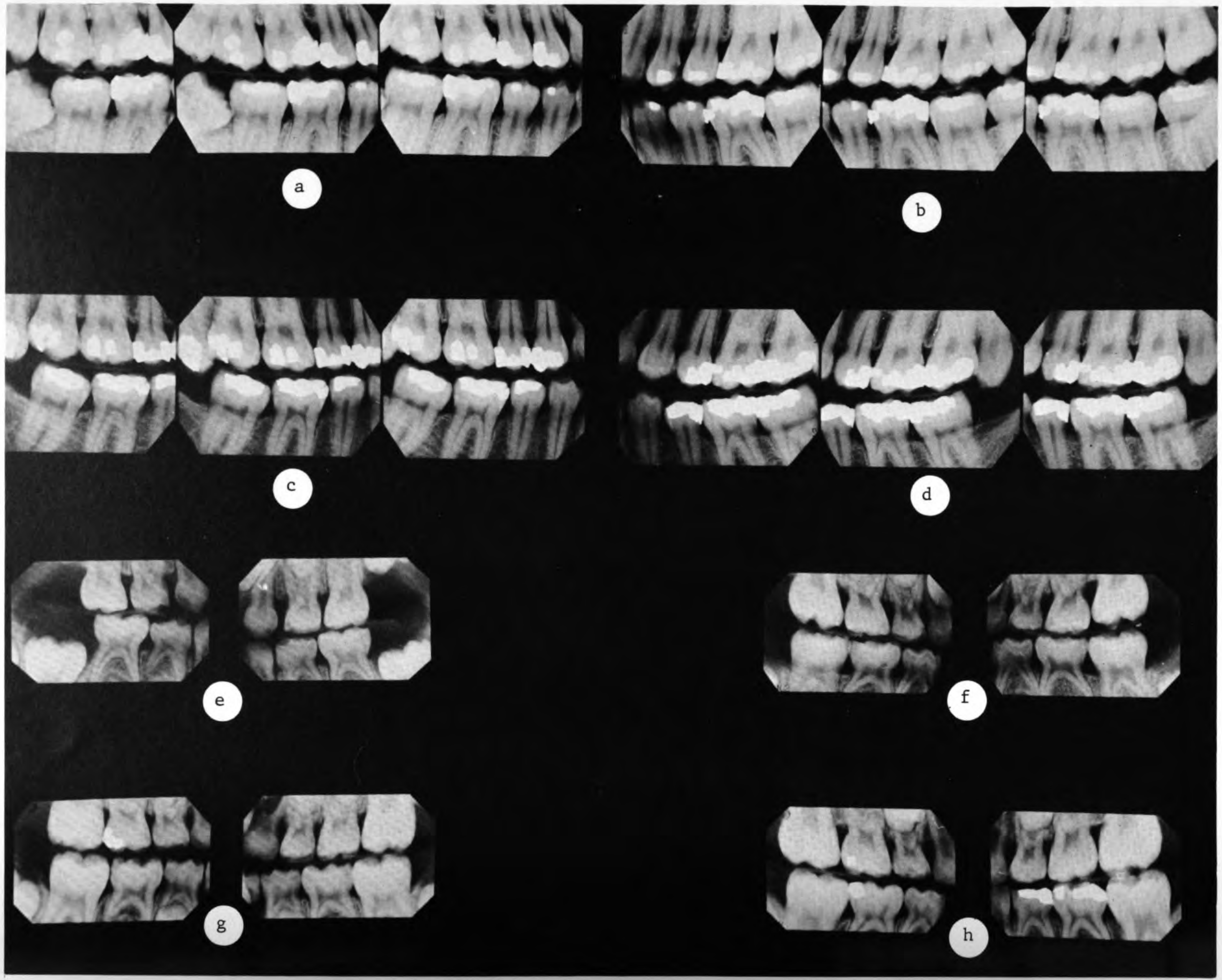

PLATE 1
Bite Wi

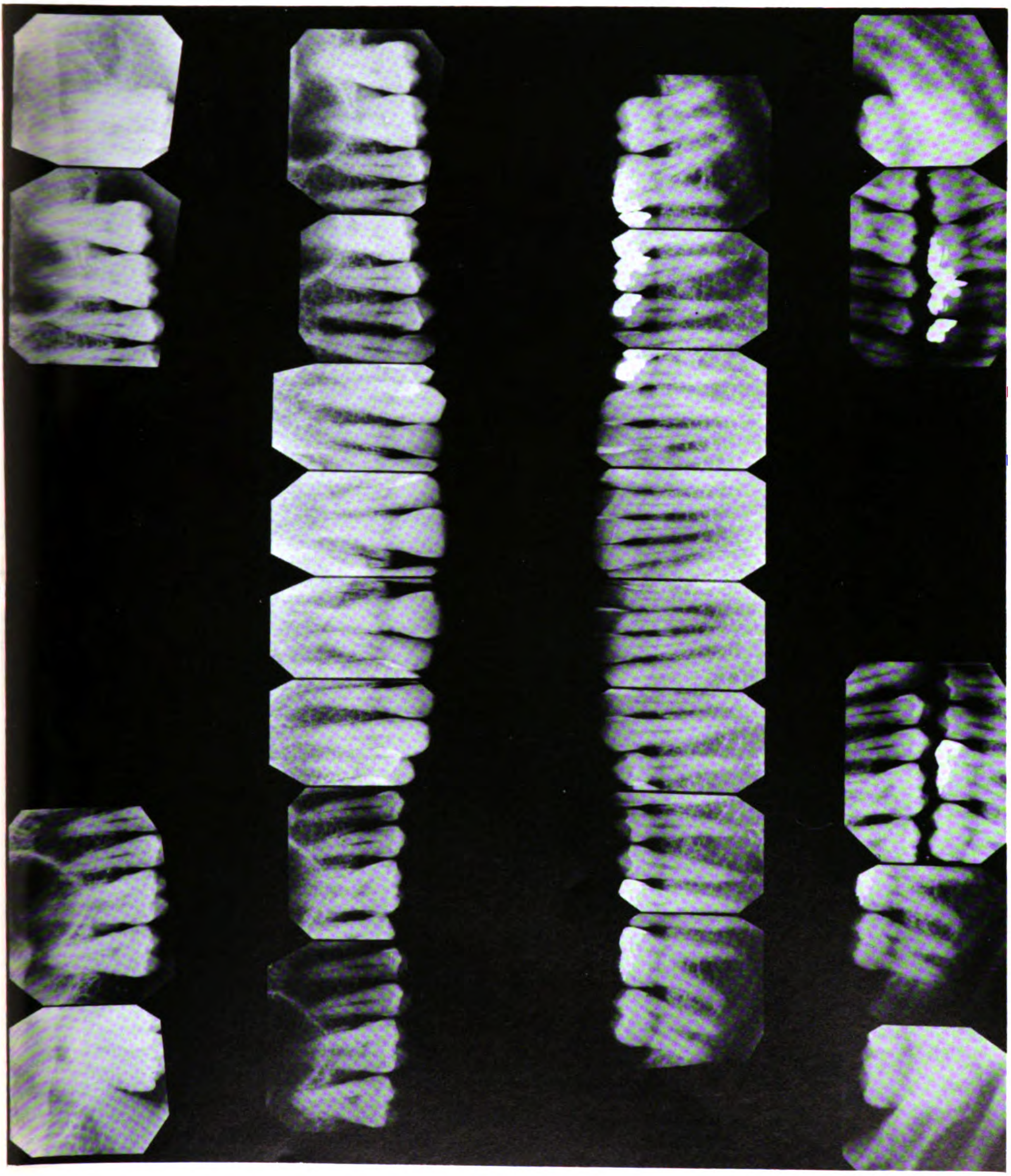

PLATE 2
Complete Dental Survey
Mature Adult

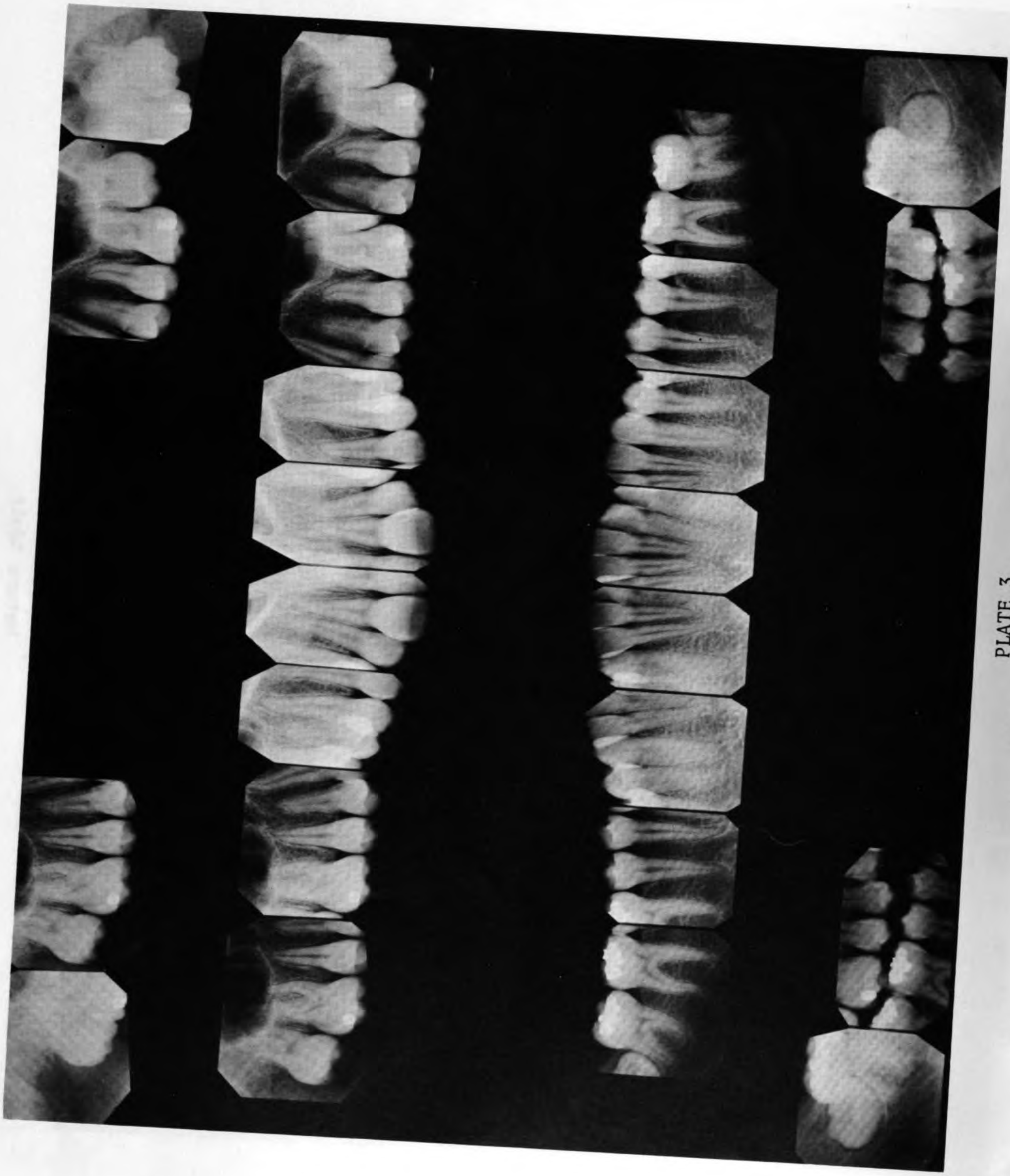

PLATE 3
Complete Dental Survey
Youn Adult

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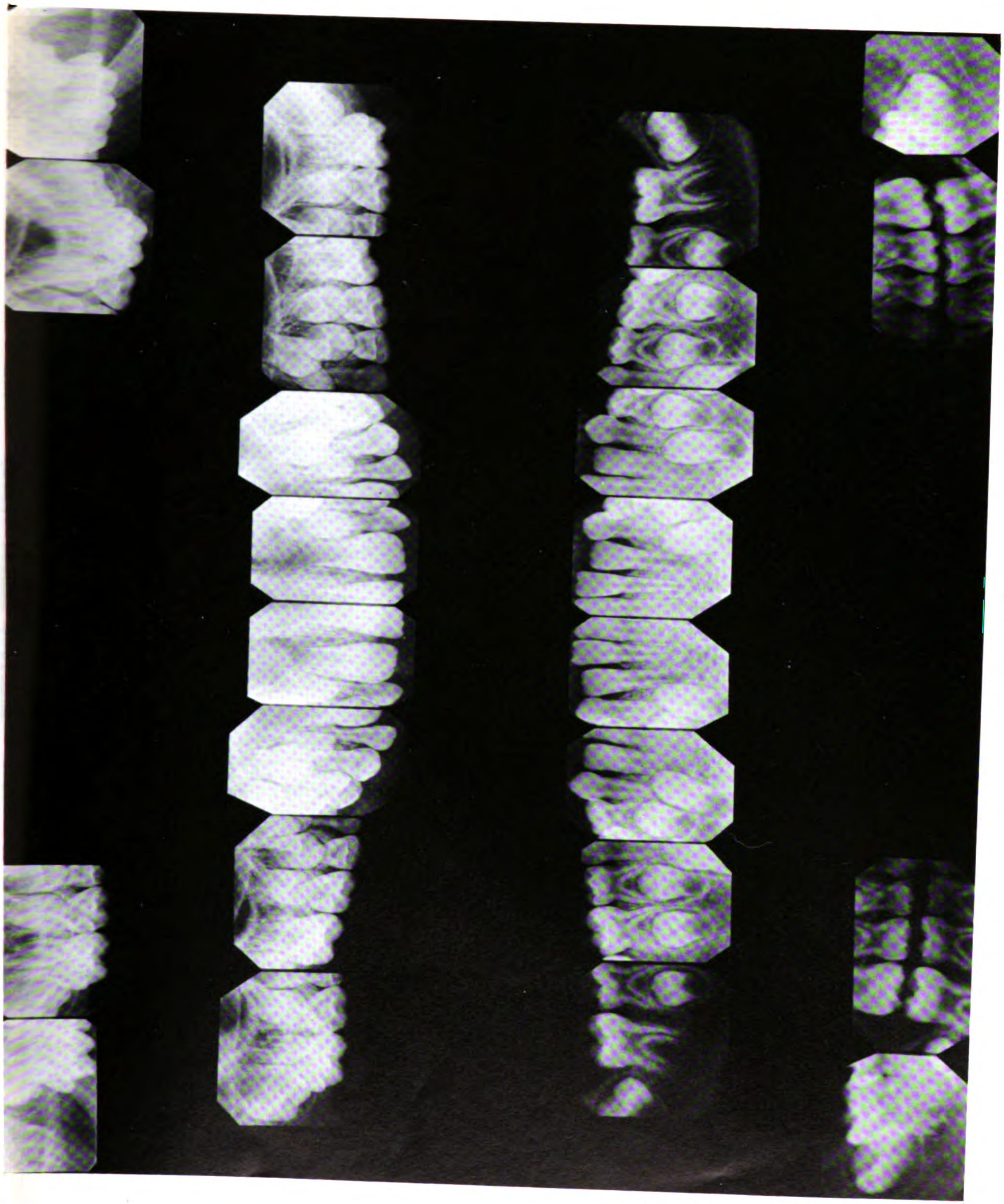


PLATE 4
Complete Dental Survey
6 Yr. Old

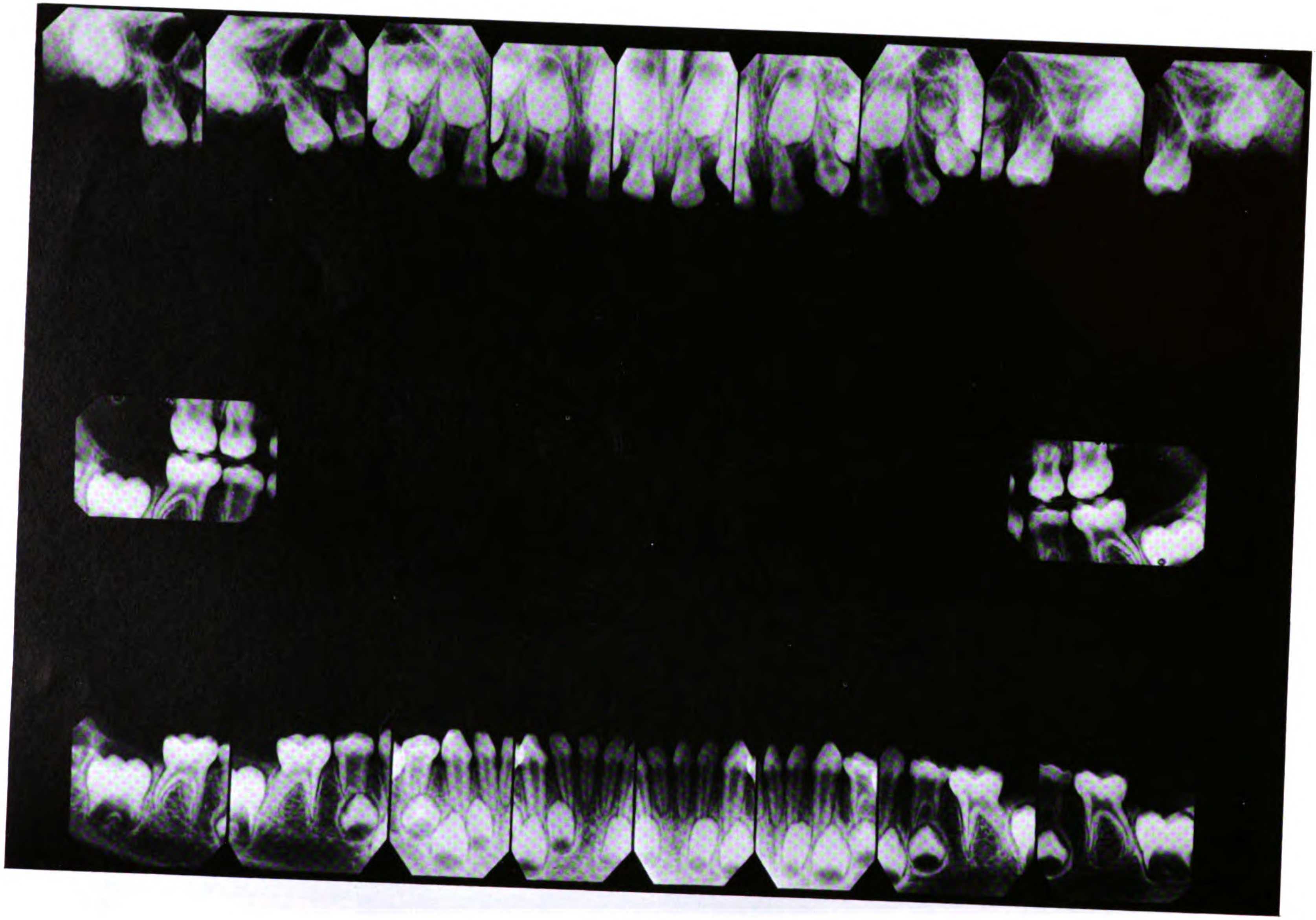


PLATE 5
Complete Dental Survey
3 Yr. Old

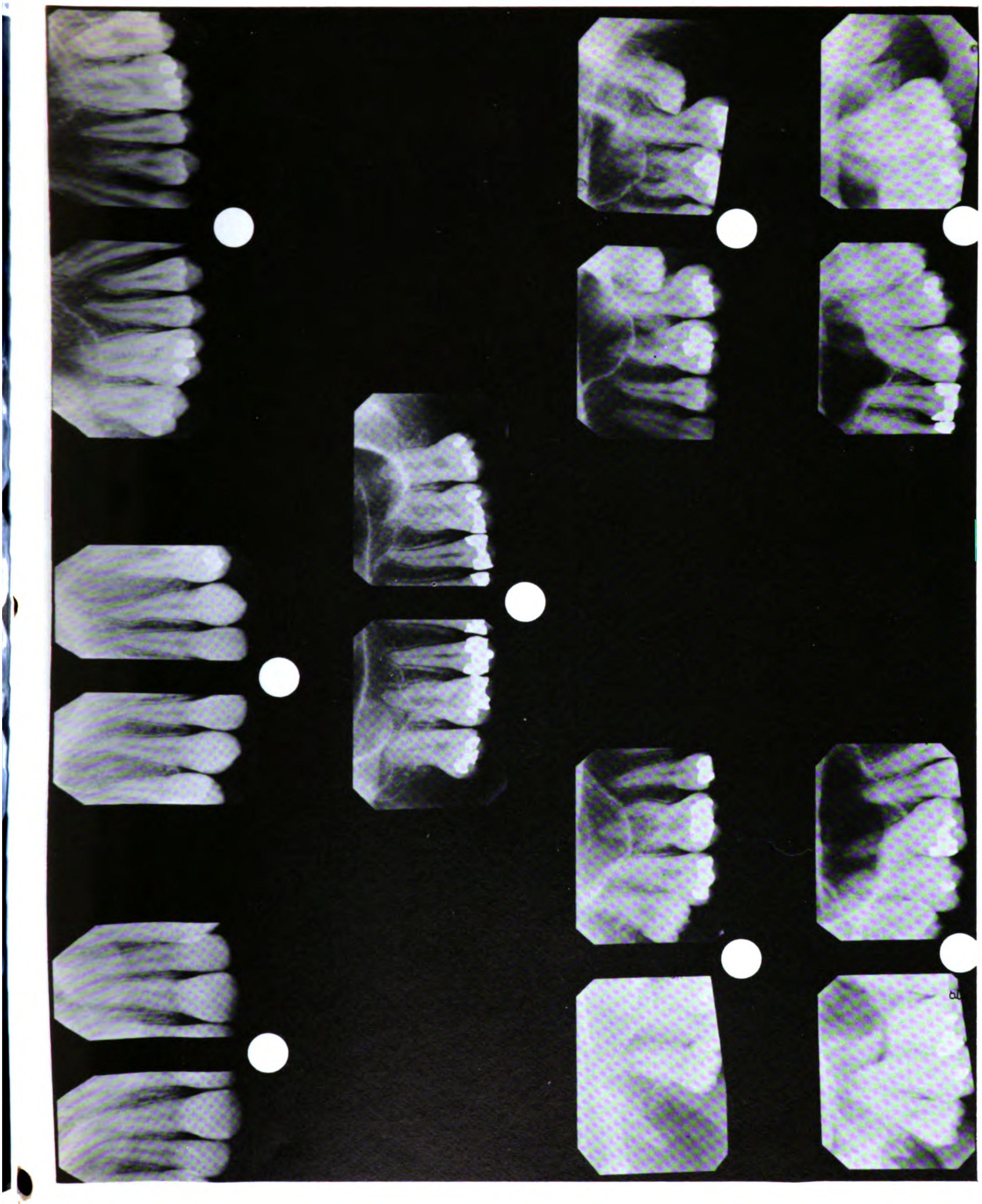


PLATE 6
Periapical Survey-Maxilla
Each Area Separately
Delineated

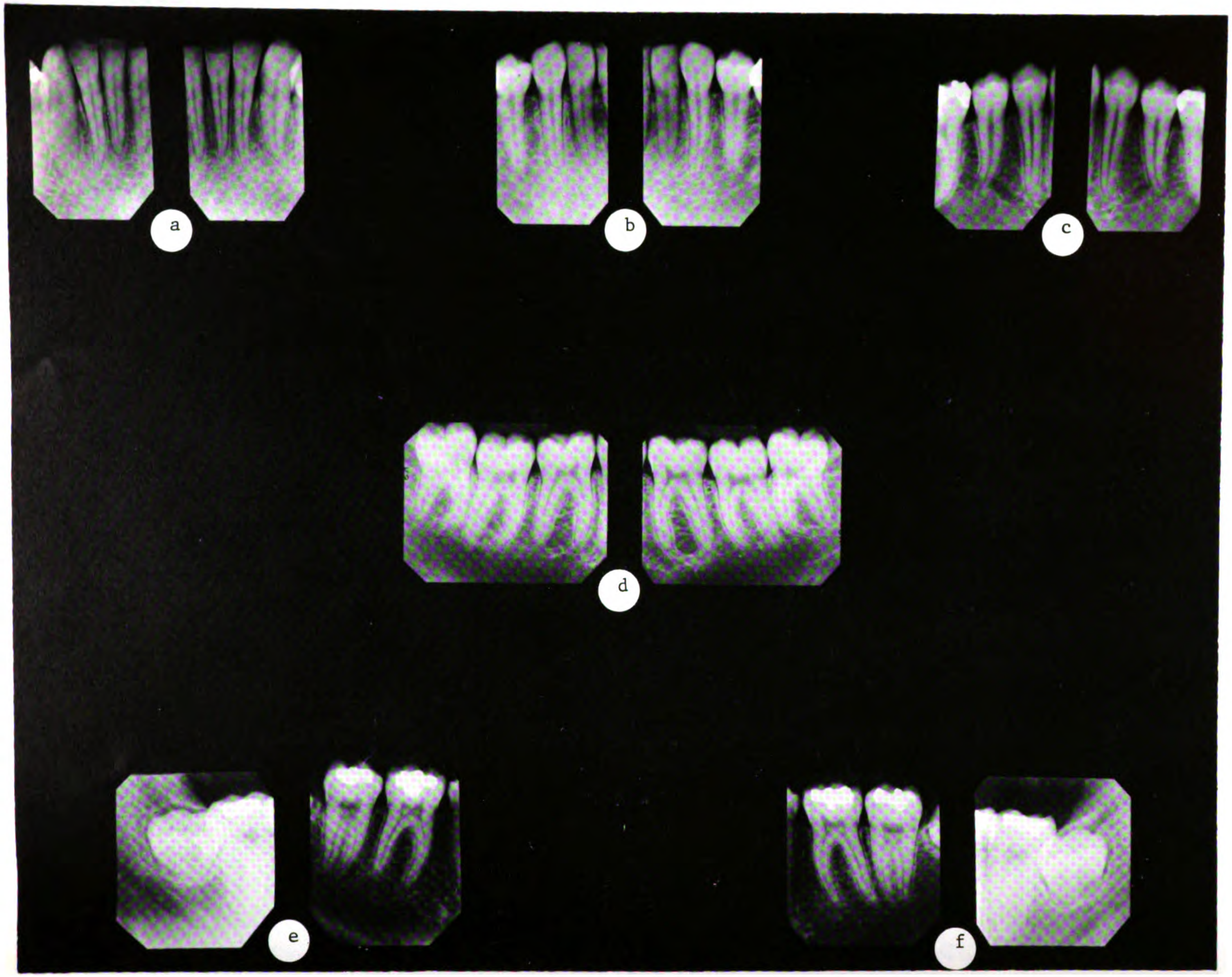


PLATE 7
Periapical Survey-Mandible
Each Area Separately
Delineated

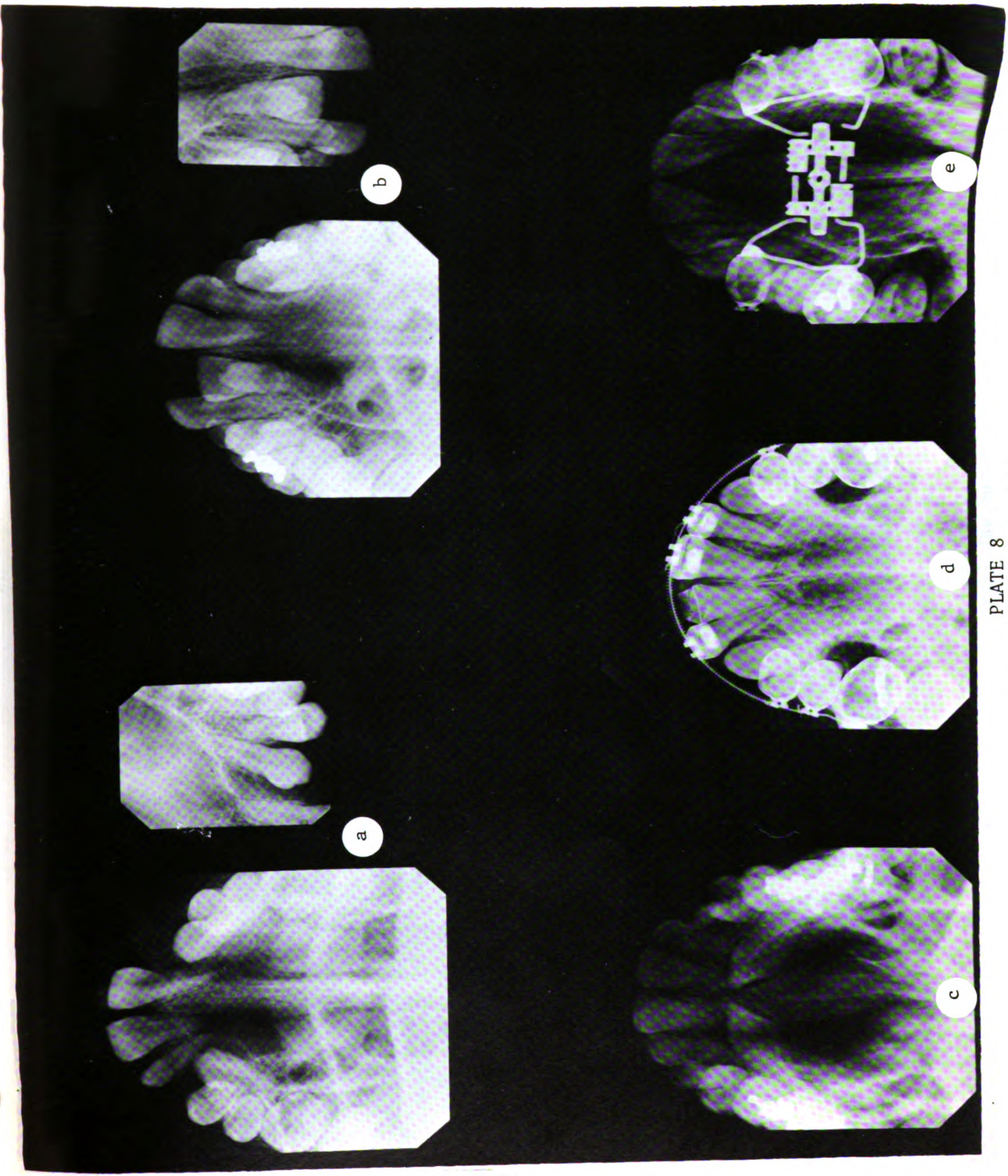


PLATE 8
Occlusal Survey-Maxilla

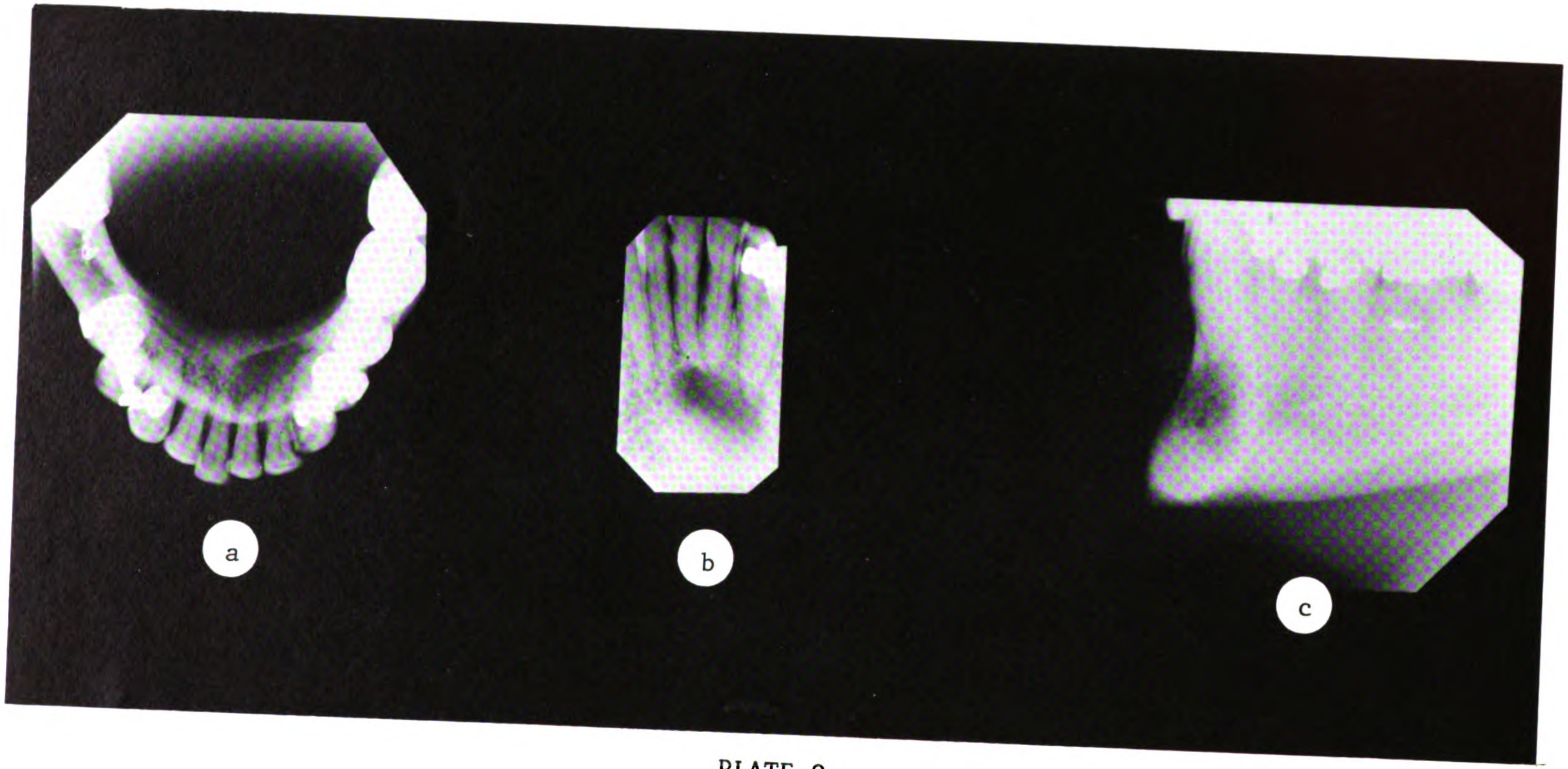


PLATE 9
Occlusal Survey-Mandible

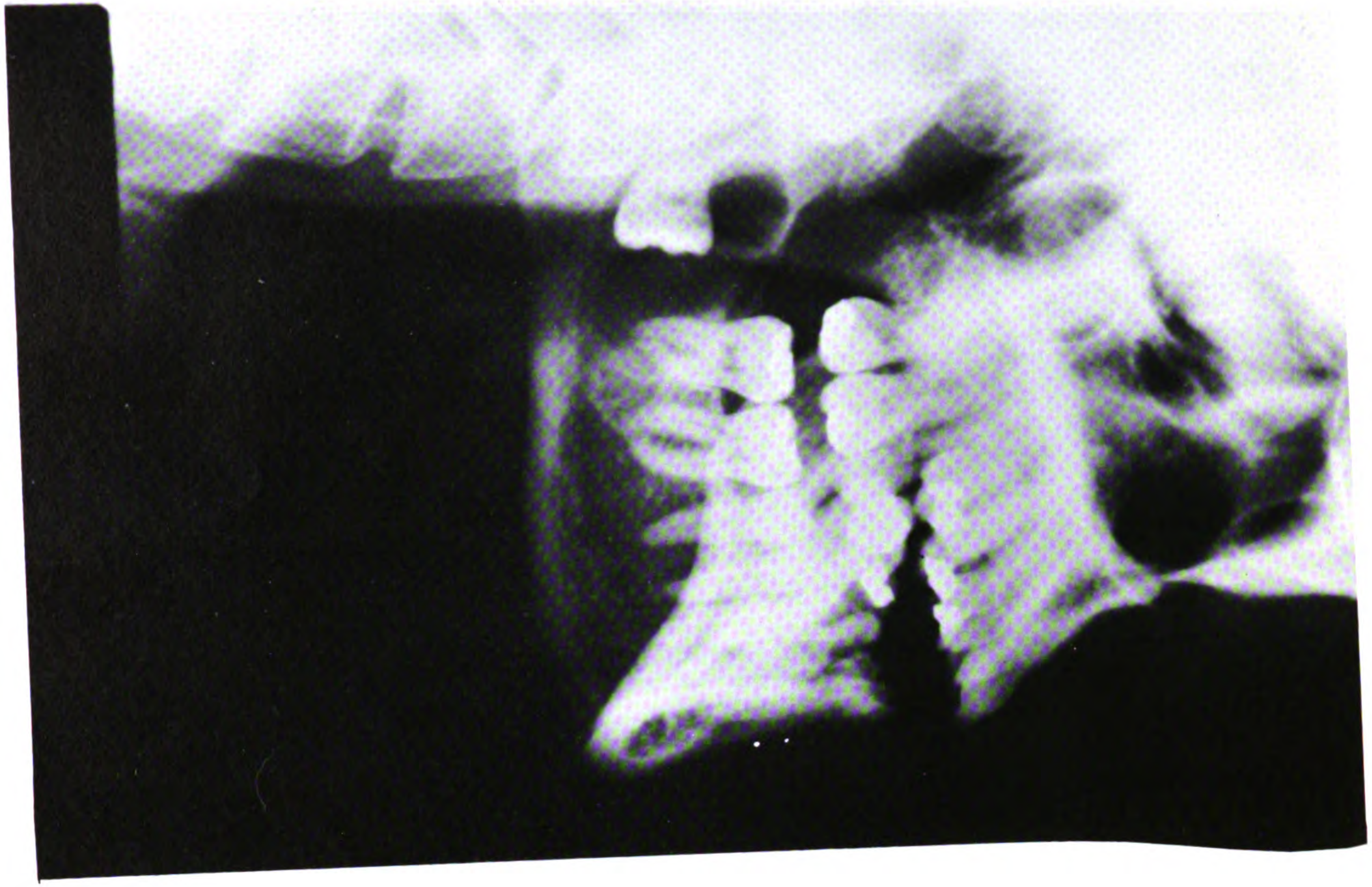


PLATE 10
Lateral Jaw Survey

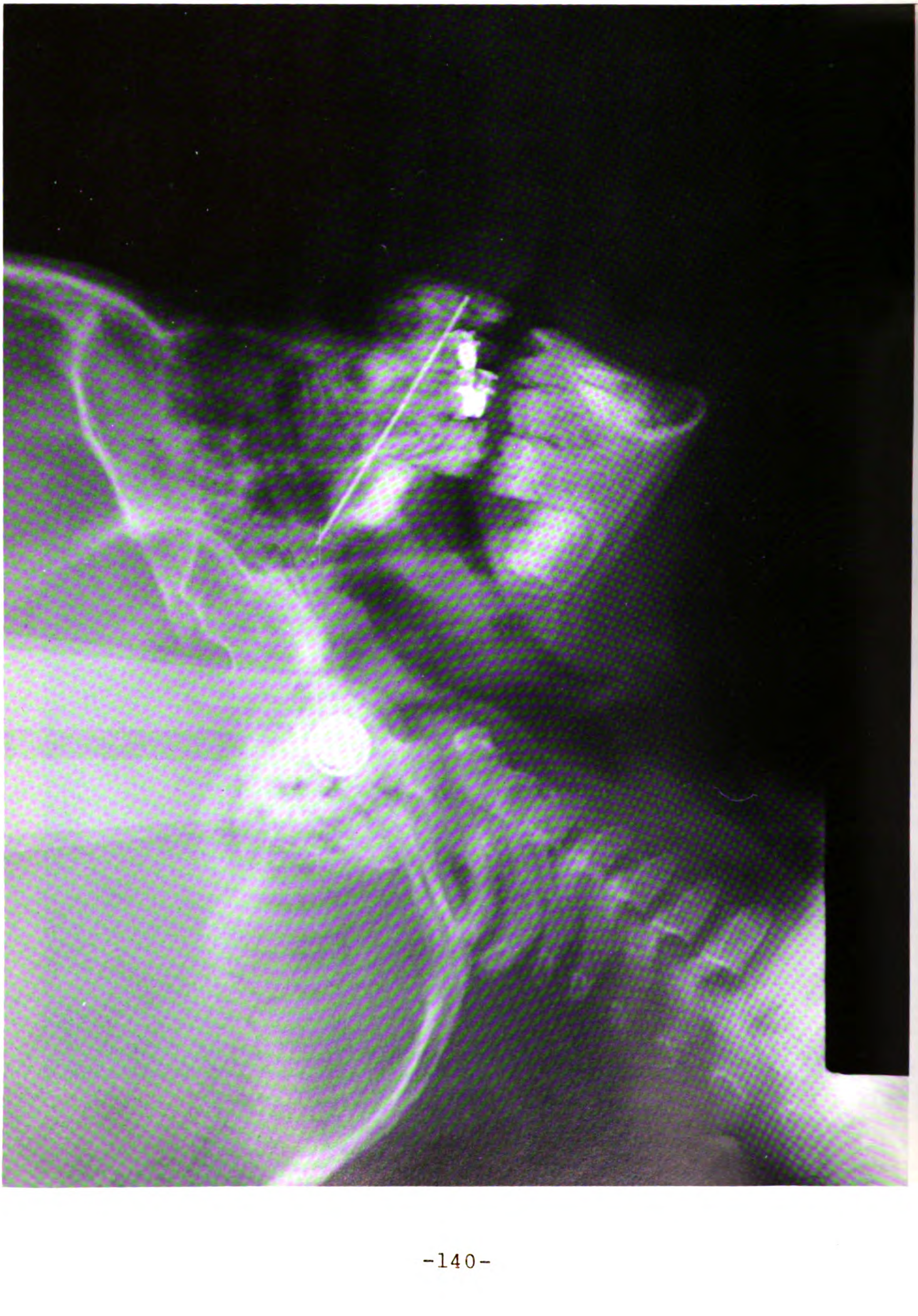


PLATE 11
Lateral Head Survey, Dental

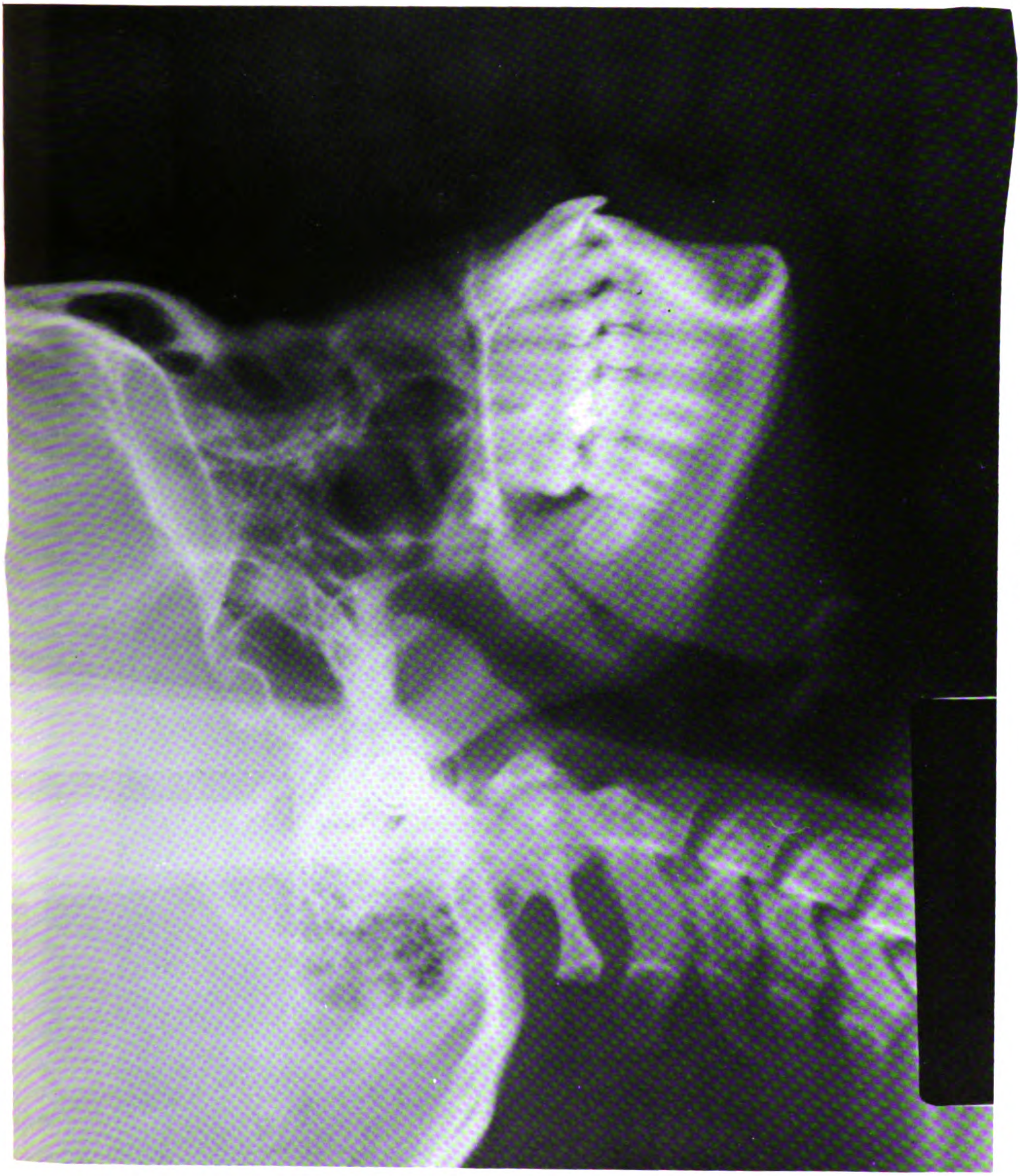


PLATE 12
Cephalometric

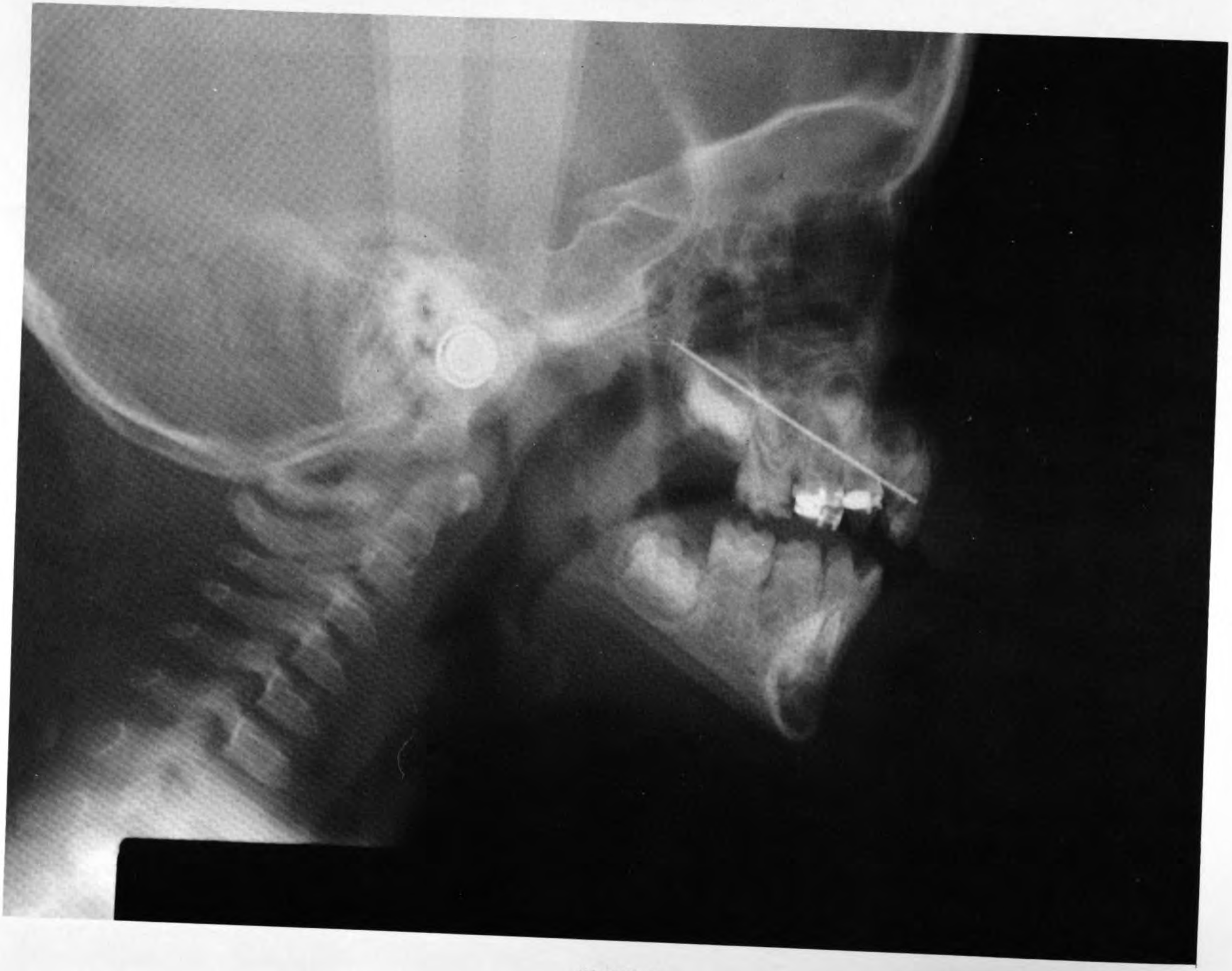


PLATE 11
Lateral Head Survey, Dental

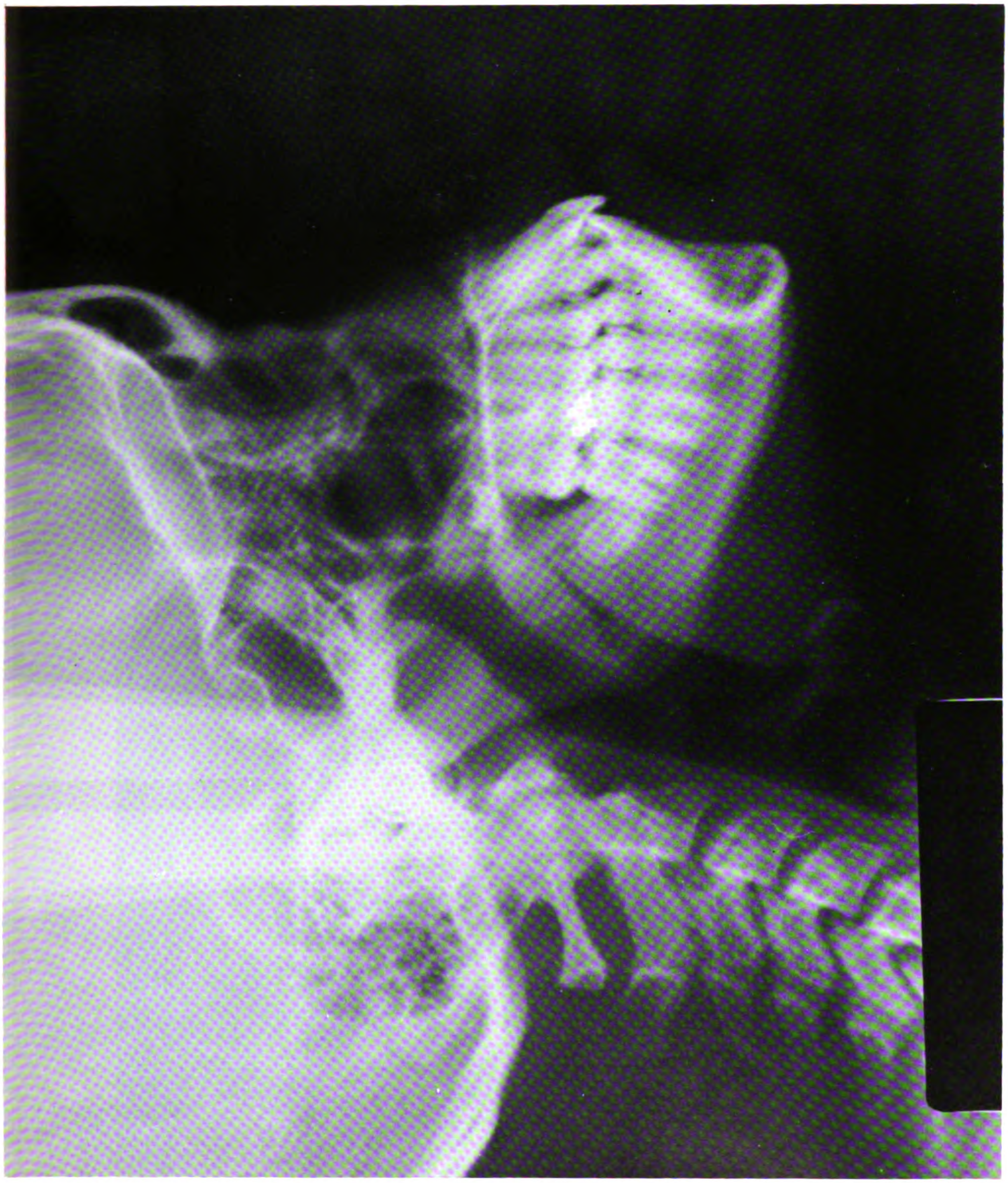


PLATE 12
Cephalometric

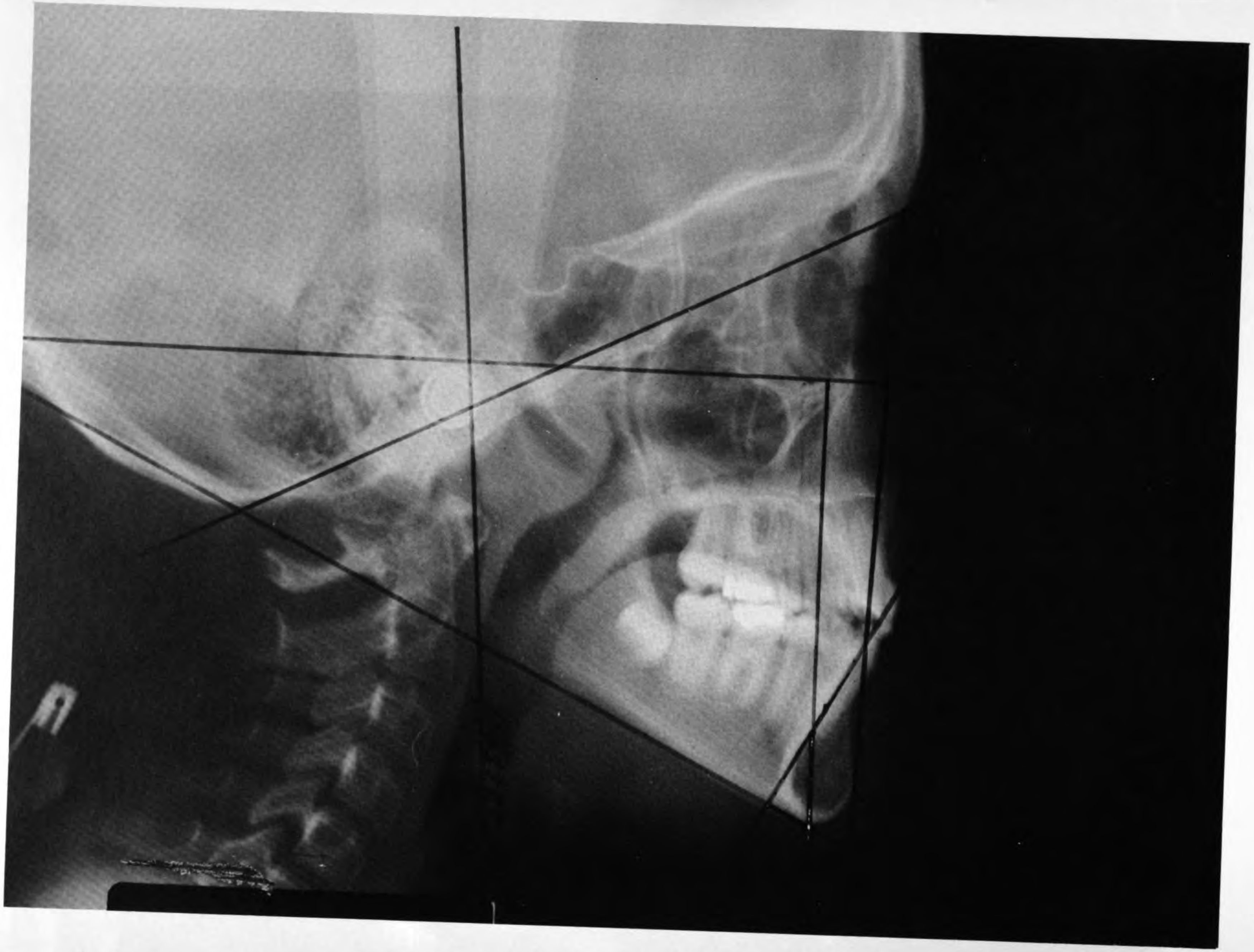


PLATE 13
Cephalometric View with
analysis drawn directly
on X-ray plate.

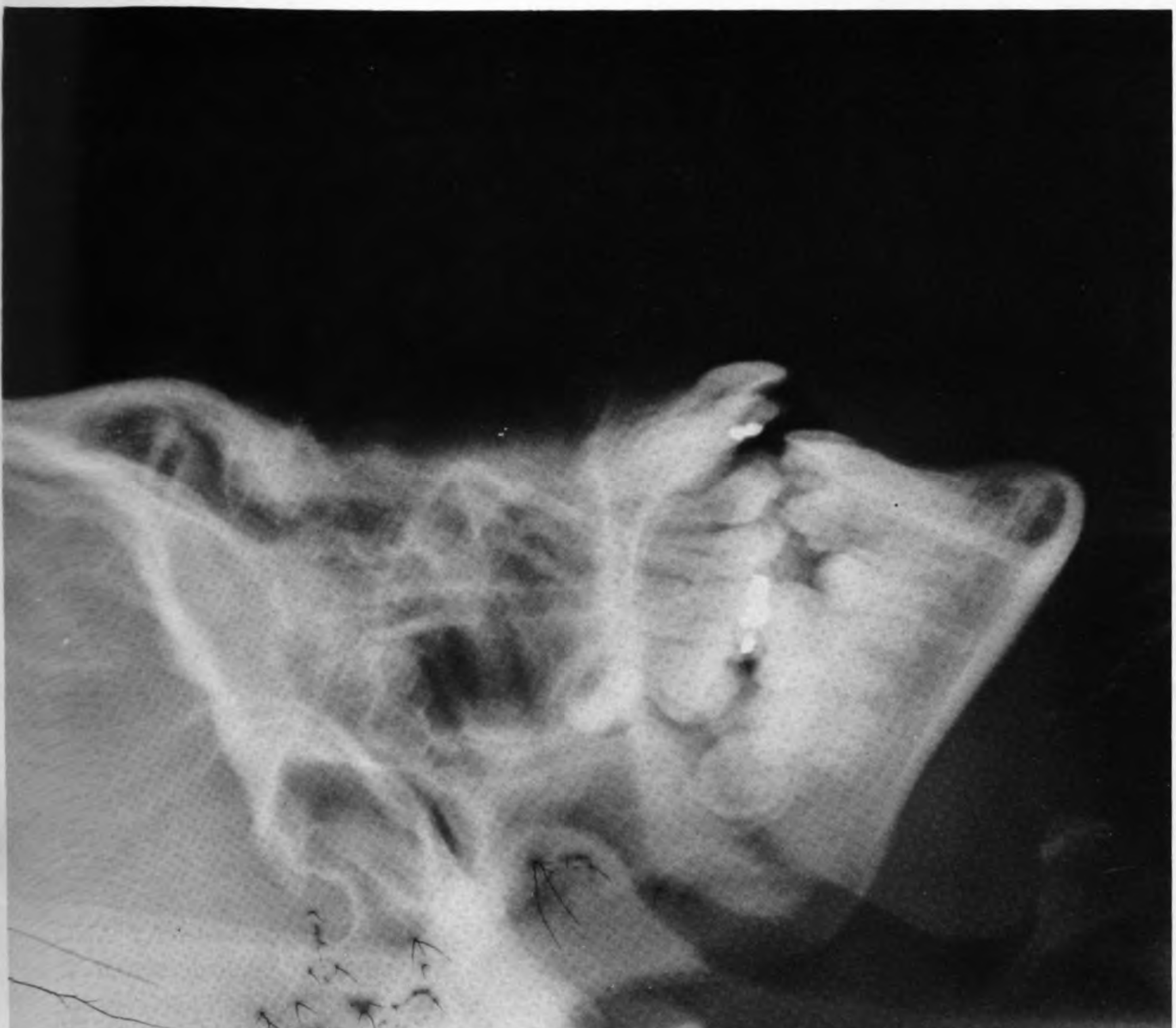


PLATE 14
The effect of static
electricity on a
radiographic film.

Appendix B

Reference Publications

CLINICAL DENTAL TERMINOLOGY, by Carl O. Boucher . . March, 1974; pub. by C. V. Mosby Co., 11830 Westline Industrial Drive; St. Louis, MO 63141

DENTAL RADIOLOGY, by Wuehrmann and Manson-Hing . . 1973; pub. by C. V. Mosby Co., 11830 Westline Industrial Drive, St. Louis, MO 63141

DENTAL RADIOLOGY FOR AUXILIARY PERSONNEL . . 1972; pub. by University of North Carolina, Extension Division, Chapel Hill, NC 27514

FUNDAMENTALS OF RADIOGRAPHY . . 10th Ed., 1960; pub. by Radiography Markets Division, Eastman Kodak Co., Rochester, NY 14650

GLOSSARY OF TERMS USED IN DENTAL RADIOLOGY . . 1963. American Academy of Oral Roentgenology; revised and edited by John H. Barr, Simon Kinsman and Albert G. Richards; pub. by Weber Dental Manufacturing Co., 2206 13th Street, Canton, OH 44705

NATIONAL BUREAU OF STANDARDS . . N.C.R.P. Report No. 34: MEDICAL X-RAY AND GAMMA-RAY PROTECTION FOR ENERGIES UP TO 10 MeV, issued March 2, 1970 . . . AND . . . N.C.R.P. Report No. 35: DENTAL X-RAY PROTECTION, issued March 9, 1970 . . . Pub. by N.C.R.P. Publications, P.O. Box 4867, Washington, D.C. 20008

ORAL ANATOMY, by Harry Sicher, M.D., DSc. . 1970 (5th Ed.); pub. by C. V. Mosby Co., 11830 Westline Industrial Drive, St. Louis, MO 63141

PROBLEMS AND LIMITATION OF CEPHALOMETRIC ANALYSIS IN ORTHODONTICS, by T. M. Graber . . . 53:439, 1956; Journal of American Dental Association, 22 East Superior Street, Chicago, IL 60611

RADIATION BIOLOGY, by Alison P. Casarett . . . 1968; pub. by Prentice-Hall, Inc., Englewood Cliffs, NJ 07632

RADIATION HYGIENE IN X-RAY TECHNOLOGY, by Simon Kinsman, Ph.D., and Ray W. Alcox, D.D.S.; pub. by Radiologic Health Section, California Department of Health, 714 P Street, Sacramento, CA 95814

RADIATION PROTECTION AND DENTISTRY, by A. H. Wuehrmann; pub. by C. V. Mosby Co., 11830 Westline Industrial Drive, St. Louis, MO 63141

DENTAL LABORATORY RADIOGRAPHY

Appendix C

1. Film Holding Devices

   Plate C 1

   a. Bite-Wing Loop
   b. Bite-Wing Tab, Pressure sensitive type adheres to film
   c. Bite Block (wood) for anterior teeth with film in vertical position
   d. Bite Block (wood) for posterior teeth with film in horizontal position
   e. Bite Block (acrylic), similar to d
   f. Bite-Wing Loop as used in a
   g. Pressure sensitive tabs as used in b
   h. Bite Block as used in c
   i. Film Holding Assembly

2. Film Holding Assembly

   Plate C 2

   a. Clamp, stainless steel
   b. Bite Block, rubber
   c. Rigid Back, stainless steel
   d. Film Packet
   e. Assembled Unit

3. X-Ray Head

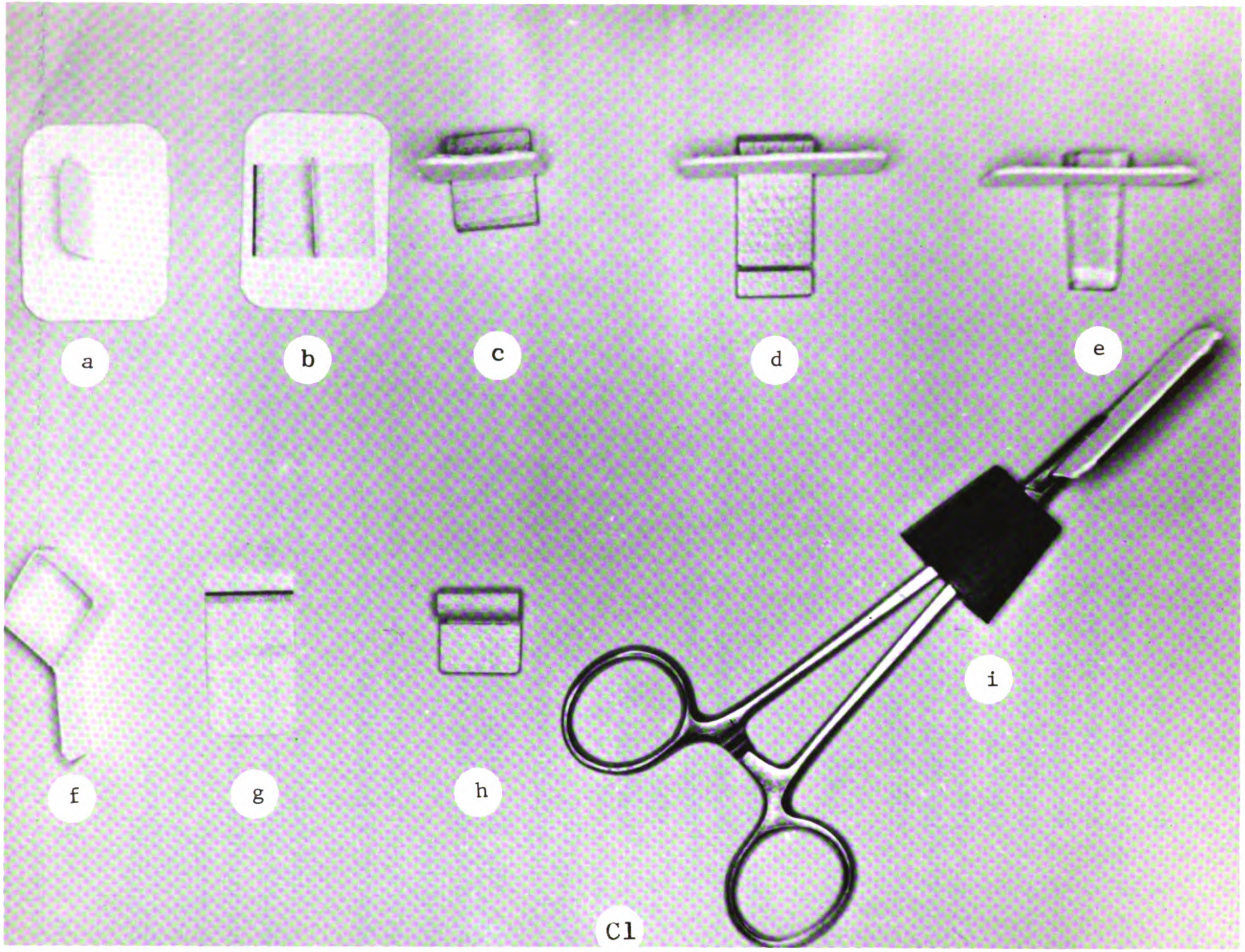
   This is a typical dental type X-ray unit, wall mounted, showing the carriage and suspension; also a long cone. The flexibility of this type unit is especially suited for intra-oral radiography.

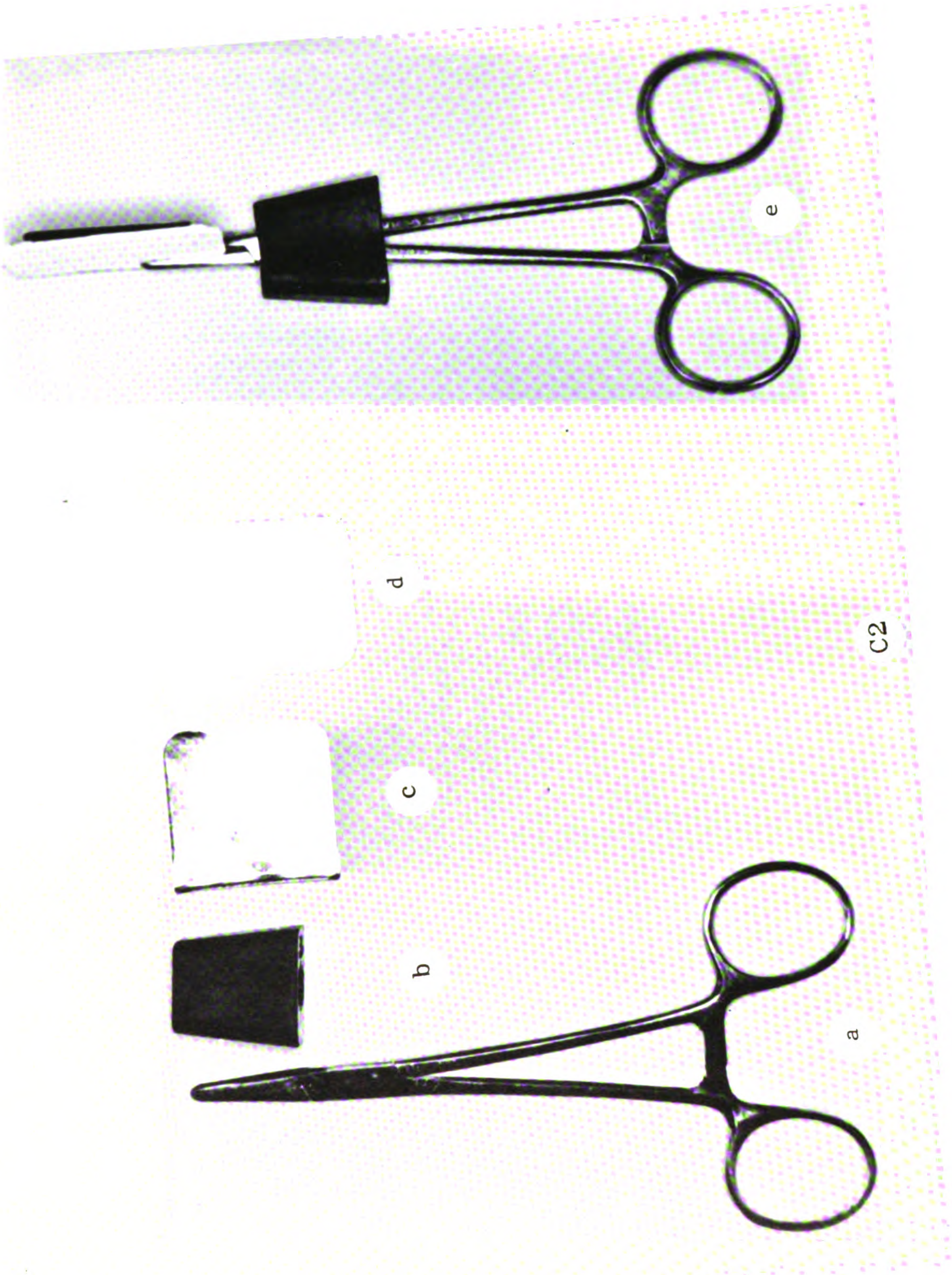
4. Laboratory Type Installation

   This installation shows two units similar to the one shown in C3; one a floor mounted unit, and the other a wall mounted unit. The control panel with electronic timer (center of photograph) is mounted on a built-in panel which is equipped with lead shielding to protect the operator.

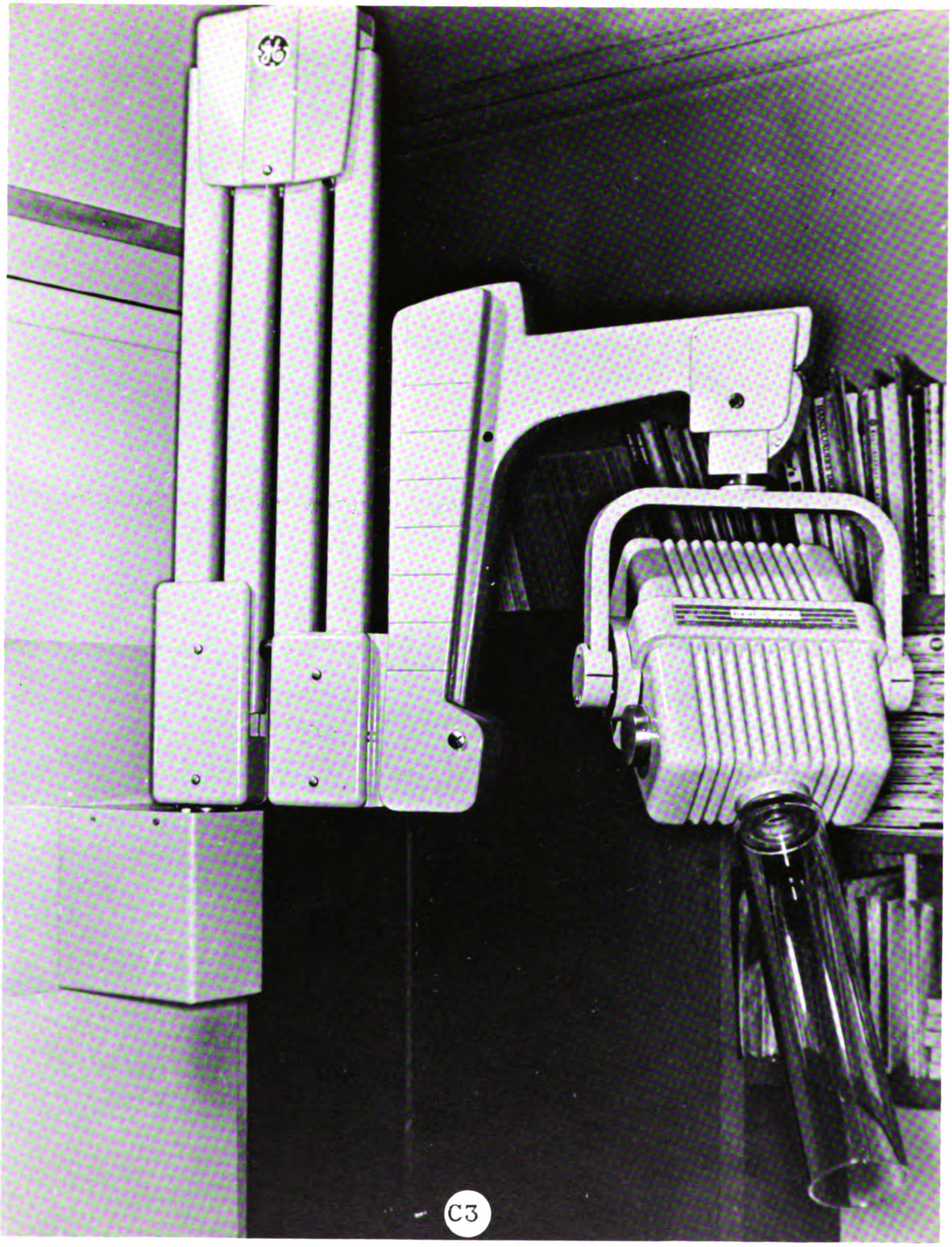
5. Cephalometer

   This is one of the better engineered cephalometers; versatile, sturdy, and precise. A Potter-Bucky diaphragm is employed in conjunction with this unit. For purposes of demonstration the cassette retainer is partly protruding from the bucky chamber.


a
b
c
d
e
f
g
h
i
C1

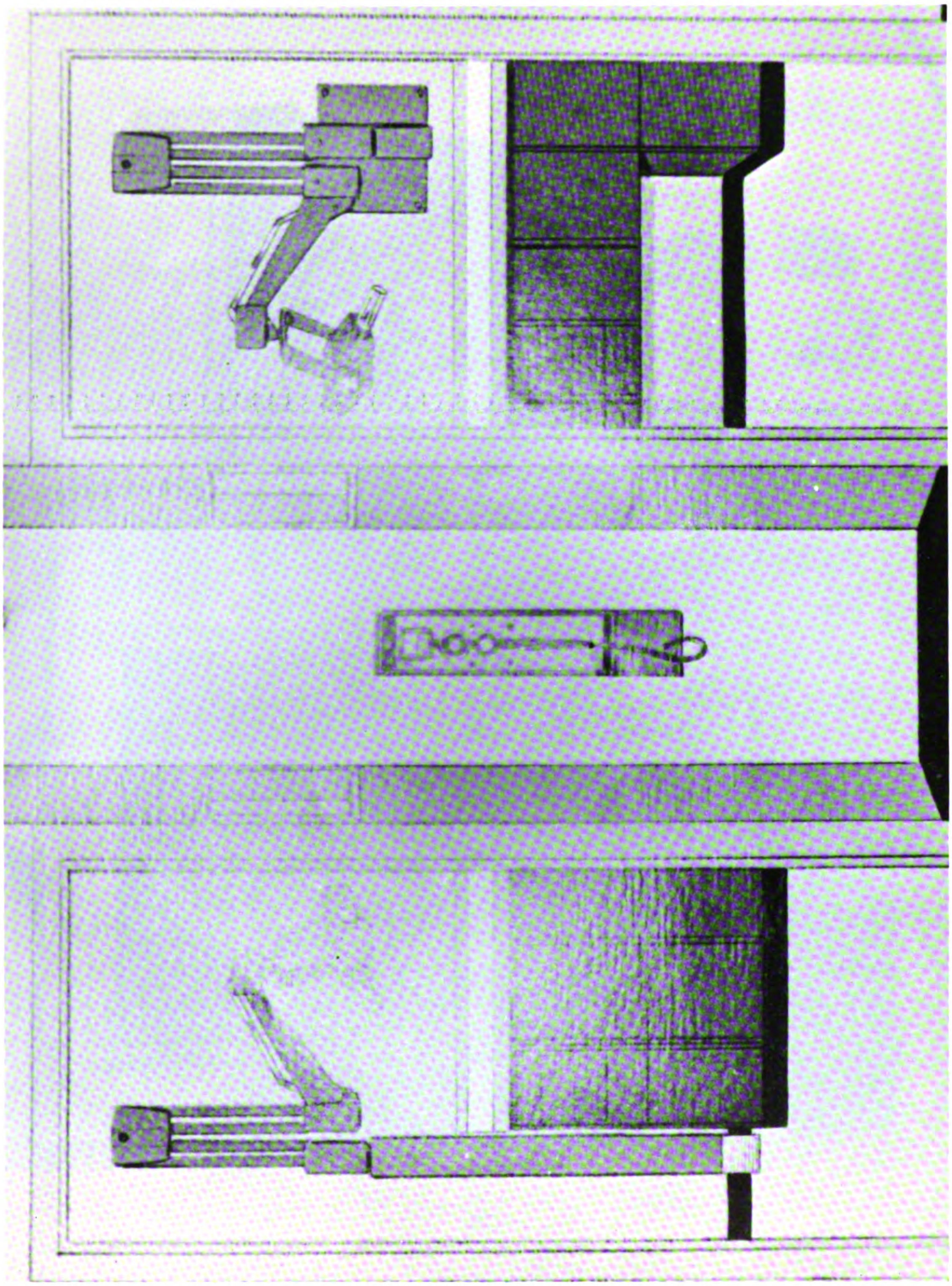


C2



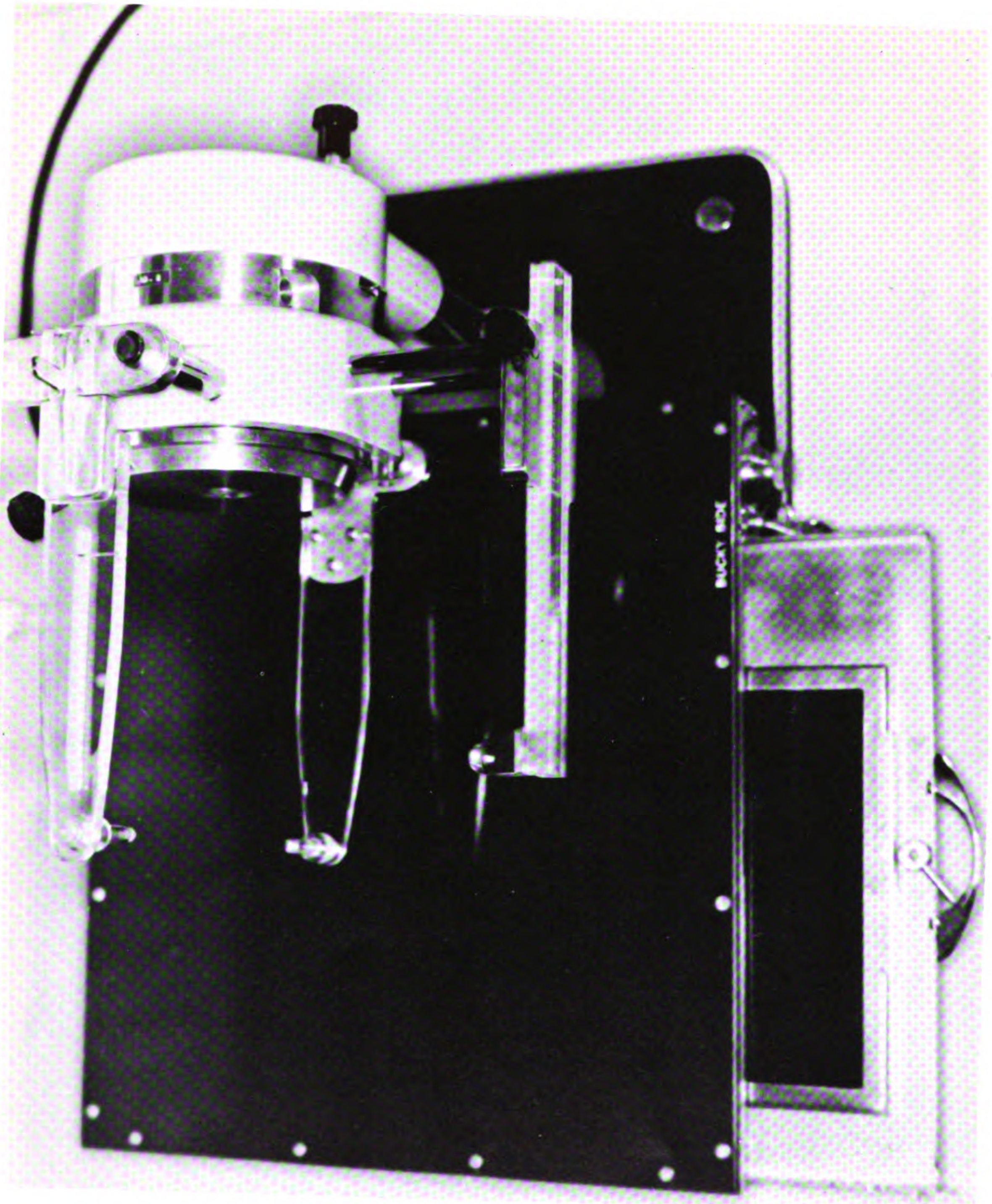
C3

X-Ray Head



C4

Laboratory Type Installation



C5

Cephalometer

Appendix D

GLOSSARY

ABSCESS: a localized collection of pus in the tissues.

ACID: a chemical substance which, in aqueous solution, undergoes dissociation with formation of hydrogen ions; has a pH that ranges from 0 to 6.9.

ALKALI: a strong water-soluble base. A chemical substance which, in aqueous solution, undergoes dissociation, resulting in the formation of hydroxyl (OH) ions.

ALUMINUM EQUIVALENT: the thickness of aluminum affording the same attenuation, under specificed conditions, as the material in question.

ALVEOLAR: pertaining to a dental alveolus or the bony process of the maxilla or mandible that contain the teeth.

AMMETER: an apparatus for measuring the amperage of an electric current.

AMPERE: a unit of electrical current.

ANATOMY: dental. The science of the form and structure of the teeth and the relationship of their parts.

ANGLE: the degree of divergence of two or more lines or planes that meet each other.

ANGULATION: the direction of the primary beam (central beam) of radiation in relation to object and film. A single direction resulting from correlated horizontal and vertical movements of the tube head.

> *Vertical angulation:* in radiography, the tube head movements that are relatively at right angles to the long axis of a tooth or part.
>
> *Horizontal angulation:* in radiography, the tube head movements that are usually related to the sagittal plane.

ANODE: the positive electrode of an X-ray tube.

ANOMALY: a developmental disturbance of minor degree, e.g., an abnormality in which a tooth or teeth have deviated from the normal in form, function or position.

ANTISEPTIC: a chemical formula that will stop or inhibit the growth of microorganisms without necessarily destroying them.

ANTRUM: a maxillary sinus.

APRON: in radiography, an apron made of materials containing metallic lead or lead compounds for the purpose of reducing radiation exposure.

ATOM: the smallest unit of an element that takes part in the formation of a compound. It has a positive nucleus surrounded by electrons.

ATTENUATION: the reduction of exposure rate upon passage of radiation through matter.

ATYPICAL: a deviation from the basic or typical.

AUTOTRANSFORMER: a transformer with a single winding, having a number of connections or taps. These taps are so arranged as to enable the operator to select a predetermined position on a control which, when the circuit is closed, will deliver a precise voltage to the high-tension primary circuit.

AXIS: a straight line around which a body may rotate. In cephalometrics, the y axis is the angle of a line connecting the sella turcia and the gnathion related to a horizontal plane. An indicator of downward and forward growth of the mandible.

BACKING: metal backing used as a support for film packet in some periapical examinations.

BARRIER: see protective barrier, both primary and secondary.

BEAM: a stream of X-rays emanating from the focal spot of an X-ray tube (see Central Beam).

BETA PARTICLE: one form of particulate radiation (one electron).

BIOLOGY: the science of life, or living matter.

BITE BLOCK: a film-holding device used in dental radiography. (The patient maintains the film position by biting against the block.)

BITE-WING FILM: a type of dental X-ray film that has a center tab or wing upon which the teeth close to hold the film in position.

BREGMA: the point at which sagittal and coronary sutures meet.

BUCCAL: adjacent to or pertaining to the cheek.

CALCULUS: tartar, the hard mineral deposit on teeth. A salivary deposit of calcium phosphate and carbonate with organic matter upon the teeth.

CANCER: a malignant neoplasm. The term is sometimes incorrectly used to include all neoplasms.

CARCINOGEN: a cancer-producing substance.

CARCINOMA: a malignant epithelial tumor.

CARIES: tooth decay; a disease of the calcified tooth structure.

CASSETTE: a device for holding radiographic film during an exposure. Screen cassettes are made up of two intensifying screens, one on each side, with the film sandwiched between them.

CATARACT: a disease of the eye in which the lens becomes opaque.

CATHODE: the negative terminal in an X-ray tube which acts as the source of electrons. Usually consists of a tungsten filament, set in a focusing cup which directs the electrons toward the anode (target).

CAVITY: a carious lesion or hole in a tooth.

CELL: the basic unit of vital tissue consistent with the physiologic concept of life.

CELL WALL: the membrane enclosing the contents of a cell.

CENTRAL BEAM: the theoretical center of X-ray beam which emanates from the target (focal spot).

CEPHALOMETER: a head positioning device used in making cephalometric radiographs. This is a precision instrument that makes it possible to reposition accurately the patient's head for serial radiographs.

CEPHALOMETRICS: the scientific study of the measurement of the head by means of radiographs.

CHART: a graphic representation.

CHROMOSOMES: the structures found in cell nuclei that carry the hereditary apparatus of the individual. They contain the genes, or hereditary factors, and are constant in number for each species.

CINERADIOGRAPHY: motion pictures made using X-rays and image intensification equipment.

COLLIMATOR: a device for confining the primary beam of radiation within a prescribed pattern.

COMPOUND: two or more elements in chemical combination.

CONDYLE: this term means head. The rounded articular surface at the end of a bone.

CONE: an attachment for an X-ray generator denoting the direction of the primary beam.

CONTACT: anatomically, the area of immediate proximity of one tooth with another in the same arch.

CONTOUR: the external shape, form, or surface configuration of an object.

CONTRAST: radiographically, the percentage of difference between the extreme blacks and whites. (Long-scale contrast indicates an increased number of grays between the extreme blacks and whites. Short-scale contrast indicates a lesser number of grays between the extreme blacks and whites.)

CONTROLLED AREA: a defined area in which the occupational exposure of personnel to radiation is under the supervision of the Radiation Protection Supervisor.

CROOKES' TUBE: a vacuum tube used by Sir William Crookes in early experimental research into cathode ray emission. It was a significant factor in the development of the X-ray tube.

CROWN: the portion of the tooth covered by enamel and delineated from the root of the tooth.

CYTOPLASM: the contents of a cell, exclusive of the nucleus, within the cell wall.

DARKROOM: a lightproof room equipped for the processing of radiographic and photographic film.

DEAD-MAN SWITCH: a switch so constructed that a circuit closing contact can be maintained only by continuous pressure on the switch.

DECIDUOUS: that which will be shed. Pertaining specifically to the first dentition of man or animal.

DENTITION: the natural teeth in position in the dental arches.

DETECTOR: in radiation, any device for converting radiant energy to a form more suitable for observation.

DEVELOPER: a chemical solution that converts the invisible image on a film into a visible one composed of minute grains of metallic silver.

DIAGNOSTIC-TYPE PROTECTIVE TUBE HOUSING: an X-ray tube housing so constructed that the leakage radiation measured at a distance of 1 meter from the source does not exceed 100 mR in 1 hour when the tube is operated at its maximum continuous rated current for the maximum rated tube potential.

DIAPHRAGM: another name for a collimator. This is, specifically, a lead disc with an opening which confines the X-ray beam to a definite pattern.

DOMINANT: in reference to a gene that will always express itself when matched with a recessive gene.

DOSE, ERYTHEMA: the amount of radiation necessary to produce a temporary redness of the skin.

DYSPLASIA: a developmental abnormality.

EDENTULOUS: lacking teeth.

EGG CELL: female germ cell, one of which in combination with a sperm cell will produce a new individual.

ELECTROLYTE: a substance which, in solution, is capable of conducting an electric current by which it is then decomposed.

ELECTROMAGNETIC RADIATION: those forms of energy propagated by wave motion as photons or distinct quanta of pure energy. The radiations have no charge, no mass and travel at the speed of light. They differ in wave length, frequency and energy and have strikingly different properties. They include radio waves, infra-red waves, visible light, ultraviolet radiation, gamma rays and cosmic radiation, along with X rays.

ELECTRON: one of the parts of an atom. It has a negative charge and very little mass (weight).

ELEMENT: a substance whose atoms have the same atomic number (same number of orbital electrons). They may differ in their nuclei, mass, atomic weight and radioactivity.

EMULSION: a suspension of silver halide salts impregnated in gelatin and used for coating radiographic and photographic film.

ETHICS: the science of moral obligation.

EXPOSURE: in radiography, the condition of being in the path of radiation.

FACTOR: a constituent, element, cause, or agent that influences a process or system.

FILAMENT: the spiral tungsten coil found in the cathode of an X-ray tube. When heated it emits electrons.

FILM BADGE: a pack of X-ray-sensitive film used for the detection and approximate measurement of radiation exposure. Used in personnel monitoring.

FILTER; FILTRATION: material in the useful beam which usually absorbs preferentially the less penetrating radiation.

Inherent filter: the filter permanently in the useful beam; it includes the window of the X-ray tube and any permanent tube or source enclosure.

Added filter: filter added to the inherent filtration.

Total filter: the sum of the inherent and added filters.

FLUORESCENCE: the emission of radiation of particular wave lengths by a substance as a result of absorption of radiation of shorter wave length. This emission occurs essentially only during the irradiation.

FOCAL SPOT: the part of the target (anode) of an X ray tube on which the electron stream is concentrated.

FOCUSING CUP: the depression in the face of the cathode which contains the filament. This design facilitates directing the electrons toward the target.

FORAMEN: a natural opening in a bone. *Incisive Foramen:* the opening in the midline of the palate. *Mandibular Foramen:* the opening on the medial aspect of the vertical ramus. *Mental Foramen:* the opening on the lateral aspect of the body of the mandible approximately below the first and second bicuspids.

FOSSA: a pit, hollow or depression.

FRANKFORT PLANE: a horizontal plane represented in profile by a line between the lowest point on the margin of the orbit and the highest point on the margin of the auditory meatus.

FREQUENCY: the number of cycles per second of a wave.

GAGGING: an involuntary retching reflex that may be stimulated sometimes by touching the posterior palatial region.

GAMMA RAYS: electromagnetic radiation of nuclear origin. Except for their origin, they are identical to X rays in their properties and effects.

GENERATOR: a system for producing electrical energy.

GENES: the fundamental unit of inheritance which is a part of the chromosomes and carries the individual traits of the organism.

GENETIC EFFECTS: genetic effects due to radiation are effects that can be transferred from parent to offspring. Any radiation-caused changes in the genetic material of sex cells.

GEOMETRIC UNSHARPNESS: an inherent property of the focal spot which results in double images of the projected X-ray beam.

GINGIVA: the mucous membrane that covers the alveolar process of the maxilla and mandible and surrounds the necks of the teeth.

GNATHION: the lowest point on the mandible at the median line.

GONION: the lowest, posterior, and most outward point on the mandibular angle.

GRID: an instrument consisting of alternate strips of radiolucent and radiopaque materials that, when placed in apposition to a film, sharply attenuates the scattered radiation.

GRID, POTTER-BUCKY: a device using a movable grid that passes between the object and film during a radiographic exposure. Grid lines are not visible with this system. (A stationary grid is a device using a grid in a fixed position. Grid lines are visible with this system.)

HALF-LIFE: the time in which a radioactive substance will loose one-half of its activity through disintegration.

HAZARD: the personal hazard existing in any area where the radiation dosage exceeds the permissable dose rate.

HYDROQUINONE: one of the chemicals used as a reducing agent in film-developing solutions.

HYGIENE: the science of health and its preservation.

HYPO: a radiographic or photographic solution in which the manifest image is fixed and hardened; it contains thiosulfate.

INHERENT FILTRATION: see Filter.

INTENSIFYING SCREEN: a cardboard coated with fluorescent material designed to fit in a cassette in contact with an X-ray film to increase the exposure efficiency.

INTENSITY: symbol is I. See radiation.

INTERPROXIMAL: between the proximal surfaces of adjoining teeth.

INTRAORAL: within the mouth.

ION: an atom or molecule that has lost or gained one or more electrons and is therefore electrically charged; also an electron.

ION PAIR: a positive and negative pair of charged particles resulting from a single ionization incident.

ISOTOPE: one or more forms of an element, each of which have the same number of protons, but differ in the number of neutrons in their nuclei. The chemical properties of all isotopes of a given element are the same.

KILOVOLT: 1000 volts; the primary determinant of the penetrating ability of X rays. Kilovolt peak (kVp) is the voltage at the crest of the wave-form. See volts and voltage.

LABIAL: pertaining to a lip.

LABORATORY: in a dental radiography laboratory, the complex of specialized rooms, equipments, facilities and skills which provide radiographic services for the dental profession.

LATENT PERIOD: the period between a radiation insult and the appearance of symptoms.

LEAD EQUIVALENT: the thickness of lead affording the same attenuation, under specified conditions, as the material in question.

LIGHT BOX: a specialized illuminator used for viewing radiographs. Usually this type of illuminator employs a flourescent lamp and an opalite glass.

LINGUAL: next to, or toward the tongue.

LIPIODAL: a proprietary iodized oil used as an opaque contrast medium in radiography.

MACROMOLECULE: giant molecules usually found in living materials or formerly living materials.

MANDIBLE: the lower jawbone.

MAS: the product of the milliamperes and the exposure time in seconds (i.e., 10mA x ½ second = 5 mAs).

MAXILLA: the right and left maxillae together form the upper jaw.

MAXIMUM PERMISSIBLE DOSE EQUIVALENT (MPD): for radiation protection purposes, the maximum dose equivalent that a person or specified parts thereof shall be allowed to receive in a stated period of time. (See Section 30265, California Radiation Control Regulations.) For radiation protection purposes, the dose equivalent in rems may be considered numerically equal to the absorbed dose in rads and the exposure in roentgens.

MILLIAMPERAGE: tube current of an X-ray tube stated in milliamperes.

MILLIAMPERE: one-thousandth of an ampere.

MILLIROENTGEN (mR): one-thousandth of a Roentgen.

MITOSIS: the reproduction of cells by cell division, the nucleus dividing first, followed by the cytoplasm.

MOLECULE: a chemical composition of two or more atoms that form a specific chemical substance.

MUTATION: a sudden change in the hereditary pattern of an organism.

NASION: the point at which the nasofrontal suture is bisected by the midsagittal plane.

NEUTRON: one of the elementary constituents of an atom. Neutrons have no electrical charge; mass is about that of a hydrogen atom.

NONCONTROLLED AREA: any space not meeting the definition of a controlled area.

NUCLEUS: 1. The center of an atom; consists of one proton for the hydrogen-1 atom and protons and neutrons for all other elements. It has a positive electrical charge. 2. The central controlling body and reproductive center of a cell.

OHM: the practical unit of electrical resistance, being the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

ORBITALE: the lowest point in the margin of the orbit.

PERSONNEL MONITOR: an appropriately sensitive device used to estimate the radiation exposure to an individual.

PHANTOM: a volume of tissue equivalent material used in place of a live person to obtain radiographs and radiological measurements.

PHOTON: a bundle (quantum) of electromagnetic energy.

PLANE: a term used to express an ideal flat surface that is supposed to intersect solid bodies; geometrically determined by the position of three points in space.

PORION: the upper edge of the external auditory meatus.

PORT: the opening in the X-ray tube housing through which the primary beam passes.

POTTER-BUCKY GRID: see Grid.

PROTON: one of the elementary constituents of an atom. It has a positive charge equal to and opposite from the negative charge of an electron.

PROTECTIVE BARRIER: a barrier of radiation absorbing material(s) used to reduce radiation exposure.

Primary protective barrier: a barrier sufficient to attenuate the useful beam to the required degree.

secondary protective barrier: a barrier sufficient to attenuate the stray radiation to the required degree.

RAD: the rad is the unit of absorbed dose of ionizing radiation. It is equivalent to an energy transfer of 100 ergs per gram of the absorbing material.

RADIATION: the transfer of energy through space or other media in the form of waves. It can be either particulate or electromagnetic.

Intensity: amount of energy per unit time passing through a unit area perpendicular to the line of propagation at the point in question.

Leakage radiation: all radiation coming from within the source housing except the useful beam. (Note: leakage radiation includes the portion of the radiation coming directly from the source and not absorbed by the source housing as well as the scattered radiation produced within the source housing).

Scattered radiation: radiation that, during passage through matter, has been deviated in direction. (It may also have been modified by a decrease in energy.)

Stray radiation: the sum of leakage and scattered radiation.

Useful beam: radiation which passes through the window, aperture, cone or other collimating device of the source housing. Sometimes called "primary beam".

RADIATION PROTECTION SURVEY: an evaluation of the radiation safety in and around an installation.

RADIOACTIVITY: the spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation.

RADIOGRAPHY: the process of making images on radiation sensitive and photo sensitive emulsions (film).

RAMUS: a branch of the mandible.

RBE: a number expressing the relative biological effect of different kinds of ionizing radiation compared to X or gamma radiation.

RECESSIVE: in genetics, a gene that will never express itself as a trait until matched with a like recessive gene.

REFLEX: the sum total of any specific involuntary activity.

REM: the amount of any ionizing radiation that will produce in man the same biologic effect as one rad of X or gamma radiation.

RETICULATION (OF FILM EMULSION): a network of wrinkles in the emulsion of an X-ray or photographic film resulting from sharp temperature differences between processing solutions.

ROENTGEN: the unit measure of ionizing radiation. It is the measure of the number of ion pairs produced (2.08×10^9) in one cubic centimeter of air exposed to a field of X or gamma radiation, at standard conditions of temperature and pressure.

ROENTGENOGRAPHY: the making of shadow images on photographic emulsions by the action of Roentgen rays (X rays).

SAFE-LIGHT: a low-powered electric light enclosed in a lightproof metal housing with an amber-colored filter on one face, to give illumination in the darkroom in which X-ray film may safely be handled for a limited period of time.

SAGITTAL: an anterior-posterior plane or section parallel to the long axis of the head.

SCREEN: in radiography, a calcium tungstate plate that is placed in contact with the film to act as an image intensifier.

SELLA TURCICA: the center of the pituitary fossa of the sphenoid bone.

SPERM CELLS: the male germ cell, one of which, in combination with an egg cell, will produce a new individual.

STRAY RADIATION: see radiation.

SURVEY: see radiation protective survey.

TARGET: the small tungsten block imbedded in the face of the anode.

TARGET-SKIN DISTANCE (TSD): the distance from the target (anode) in the X-ray tube to the skin of the person receiving the radiation (being radiographed).

TECHNIQUE: a detailed method and sequence in producing radiographs.

THERMIONIC EMISSION: the release of electrons when a material is heated.

TOTAL FILTRATION: inherent filtration plus added filtration in an X-ray tube.

TRAGION: the notch just above the tragus of the ear.

TRAGUS: a prominence in front of the opening of the external ear.

TROUGH: the low area in a wave form; the opposite of a wave crest.

TUBE HOUSING: the lead-shielded container that holds the X-ray tube, transformer and insulating oil.

USEFUL BEAM: see radiation.

VOLT: the unit of electromotive force which when applied to a conductor of one ohm resistance will produce a current of one ampere.

VOLTAGE: the electrical potential or potential difference as expressed in volts.

WAVE LENGTH: The distance between the peaks of waves in any wave form, such as light and X-rays.

WINDOW, RADIATION: the thin wall of glass in an X-ray tube opposite the focal spot. The primary X-ray beam passes through this window.

X-RAY TUBE: the glass vacuum tube that contains the anode, cathode and filament which are designed to produce X radiation.

APPENDIX E

RELATION OF RADIATION INTENSITIES AND DISTANCE FROM X-RAY (GENERATOR) MACHINE

Consider the following two examples:

1. The Roentgen output, or radiation intensity at the end of an 8-inch pointing device (cone) is 1.2 R per second. What would the intensity be at the end of a 16-inch pointing device, using the same setting on the X-ray generator?

Since the 16-inch distance is twice the 8-inch distance, the radiation is reduced by a factor equal to the inverse, or reciprocal, of the square of the new distance, which is two times as great as the first distance considered. The inverse of two is 1/2, and this figure squared is $(1/2)^2$, or 1/4. One-fourth of the Roentgen output at eight inches is 1/4 of 1.2 R/sec., or 0.3 R/sec., or 300 mR/sec., which is the radiation intensity at the end of the 16-inch pointing device.

2. Suppose you were using an 18-inch cone with a generator whose Roentgen output at a target-to-skin distance of 18 inches was 0.2 R/sec., what would be the radiation intensity at a target-to-skin distance of six inches? Since six inches is 1/3 of the 18-inch distance and the inverse of 1/3 is three, and three squared is 3^2, or 9, therefore the radiation intensity at six inches is nine times that at 18 inches, or nine times 0.2, or 1.8 R/sec.

Another way the inverse square law can be remembered is that the product of the intensity (I_1) at any distance from the target, multiplied by the square of the distance under consideration $(D_1)^2$, is equal to the intensity (I_2) at some other distance (D_2), multiplied by the square of the second distance $(D_2)^2$. The units for measuring the distance are more conveniently handled if they are both in the same units – i.e., inches, feet, cms., etc. – and the radiation intensities will likewise be in the same units. Expressing these mathematically, we have the following equation:

$$I_1 \times (D_1)^2 = I_2 \times (D_2)^2$$

Where I_1 is the first intensity you want to consider and D_1 is the distance at which I_1 was measured. I_2 is the second intensity measured or calculated at a distance D_2. Using this equation and Example 1 above, we have:

I_1 = 1.2 R/sec.

I_2 = $\underline{X}$, $\underline{\text{or unknown}}$

$(D_1)^2 = 8^2$ = square of the first distance

$(D_2)^2 = (16)^2$ = square of the second distance

$I_1(D_1)^2 = I_2(D_2)^2$

$$1.2 \text{ R/sec.} \times 8^2 = X \times (16)^2 \text{ or } (16)^2 X = 1.2 \text{ R/sec.} \times 8^2$$

Solving for X:

$$X = \frac{1.2 \text{ R/sec.} \times 8^2}{(16)^2} = 1.2 \text{ R/sec.} \times \frac{8^2}{(16)^2}$$

$$= 1.2 \text{ R/sec.} \times \left[\frac{8}{16}\right]^2 = 1.2 \text{ R/sec.} \times (1/2)^2$$

$$= 1.2 \text{ R/sec.} \times 1/4 = 0.3 \text{ R/sec.}$$

Using the equation $I_1 \times (D_1)^2 = I_2 \times (D_2)^2$ and Example 2, we have:

I_1 = 0.2 R/sec.

I_2 = X, or unknown

$(D_1)^2 = (18)^2$ = square of first distance

$(D_2)^2 = (6)^2$ = square of second distance

Substituting, we have:

$$0.2 \times (18)^2 = X \times 6^2 \text{ or } 6^2 \times X = (18)^2 \times 0.2$$

$$X = \frac{(18)^2}{6^2} \times 0.2 = \left[\frac{18}{6}\right]^2 \times 0.2$$

$$= 3^2 \times 0.2 = 9 \times 0.2$$

$$= 1.8 \text{ R/sec.}$$

This information can be secured by utilizing the diagram preceding this write-up, which shows the calculations carried out for the distances used in cephalometrics (five feet).

If you know the Roentgen output of your X-ray tube (generator) at any distance, you can secure the amount of radiation intensity at any point closer or at greater distances from the target in the tube, by using the factors of comparison for these two distances. Even if you do not know the exact Roentgen output at any particular distance from the target, when you change pointing devices you can read from the chart the fraction of the original radiation you are getting at the greater distance or the number of times the amount of the original intensity you will experience at a shorter distance. This information is necessary to couple with your exposure time for appropriate exposures as discussed in the following paragraph.

In making radiographs, it is desirable to have the same amount of radiation reach, expose, or interact with the film. The radiation exposure which is sometimes referred to as the dose is the product of the intensity and the exposure time. In Examples 1 and 2, used above, if you were attempting to deliver the same amount of radiation to the film under the new conditions as those used previously, the exposure time would be changed accordingly. If the intensity I_1 multiplied by the exposure time t_1 is to be kept at a constant value, whatever it may be:

$$I_1 \times t_1 = I_2 \times t_2$$

where I_2 is the second or new intensity at a different target-to-skin distance, and t_2 is the corresponding exposure time.

In Example 1, if the exposure time was 0.5 second, using the 8-inch cone, what should it be to give the same film exposure at 16 inches? Since $I_1 = 1.2$ R/sec., $t_1 = 0.5$ sec., $I_2 = 0.3$ R/sec., $t_2 = X$, and $I_1 t_1 = I_2 t_2$, then 1.2 R/sec. x 0.5 sec. = 0.3 R/sec. x X. Or:

$$0.3X = 1.2 \times 0.5, \text{ or}$$

$$X = \frac{1.2 \times 0.5}{0.3} = 4 \times 0.5$$

X = 2 seconds, the necessary exposure time at a 16-inch distance.

In Example 2, if the exposure time at 18 inches were 2.7 seconds, what exposure time is necessary at six inches?

I_1 = 0.2 R/sec.
t_1 = 2.7 seconds
I_2 = 1.8 R/sec.
t_2 = X

$$\begin{array}{rcl} I_1\ t_1 & & I_2\ t_2 \\ 0.2\ \text{R/sec.} \times 2.7\ \text{secs.} & = & 1.8\ \text{R/sec.} \times X \\ \text{or } 1.8X & = & 0.2 \times 2.7 \\ X & = & \dfrac{0.2 \times 2.7}{1.8} = \dfrac{2.7}{9} = 0.3 \\ X & = & 0.3\ \text{sec.} = \text{exposure time at six inches target-to-skin distance.} \end{array}$$

OPERATOR EXPOSURE TO SCATTER RADIATION

The exposure or dose (D) is the product of the intensity of radiation and the exposure time (t), or D = I x t. Since we are concerned only with X-rays, the exposure or dose D will be in Roentgens. You can measure the exposure time in any units (seconds, minutes, hours, etc.) that you desire. However, for convenience in calculating the exposure, the intensity and time will have to be converted to the same units of time – that is, the intensity of radiation will have to be in milli-Roentgens per second, or minute, or hour, depending on the unit in which you prefer to measure your total exposure time. However, for most of the portable radiation survey meters, the units used are milli-Roentgen/hr, or mR/hr.

For the calculations, let's consider one average case and use these factors, with an assumption that the operator stands in a similar position with respect to the patient and the direction of the beam, during the production of all dental radiographs, and that we are considering only scatter radiation at the position of the operator.

EXAMPLE: Given, the average working situation of:

A. 55 = number of dental films exposed per week
B. 1.2 seconds (secs) = average exposure time per film
C. 1200 mR/hr = intensity of scatter radiation from a phantom or patient, measured at a distance of three feet from the patient, and at a location of 45° from the direction of the X-ray beam during a bitewing exposure using 90 kVp.

To find: the radiation exposure to the operator per year.

With D = I x t, to solve for D we need both I and t, which were given. All that is needed is to convert to appropriate units.

Since I was given in mR/hr, let's calculate our exposure time on the basis of a week. This will naturally be the product of the number of films per week (55) and the average exposure time per (1.2 seconds). Or,

$$55\ \frac{\text{films}}{\text{week}} \times 1.2\ \frac{\text{secs}}{\text{film}} = 66\ \frac{\text{seconds}}{\text{week}}$$

Since there are 60 seconds in a minute and 60 minutes in an hour, the average operator exposure time in minutes per week will be 66/60 or 1.1; and expressed in hours it will be one-sixtieth of this value, or 1.1/60 = average operator exposure time in hours per week.

The exposure time can be converted into exposure – which is sometimes called dose – by using the relationship stated in the first paragraph or by multiplying the rate of scatter radiation received by the operator by the time he spends in this radiation field, as follows:

$$\begin{aligned} D &= It \\ &= 1200 \text{ mR/hr} \times \frac{1.1\text{/week}}{60} \\ &= 22 \text{ mR/week.} \end{aligned}$$

The radiation protection guides produced by the Federal Radiation Council lists, for occupationally exposed people, 0.1 R, or 100 milli-Roentgens a week as the upper level of exposure. Your exposure should be lower than this figure of 100 mR/week. If your operation is similar to those in the example which used the national averages of 55 dental films exposed per week, and an exposure time of 1.2 seconds per film, and the intensity of scatter radiation approximately 1200 mR/hr, your exposure would be approximately 22 mR per week. If your operation is characterized by better radiation hgyiene practices, your exposure should be lower than 22 mR/week.

Since the average exposure of the operator to scattered X-radiation in dental radiography is small and less than the radiation protection guides, the exposure is frequently recorded on an annual basis. If you know the exposure for a week, the yearly exposure is naturally the product of the weekly rate by the number of weeks worked per year, which is generally considered to be 50. Therefore,

$$\frac{22\text{mR}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = \frac{1100 \text{ mR}}{\text{year}} \text{ or } \frac{1.1\text{R}}{\text{year}}$$

An alternate way to figure the annual exposure is to calculate the exposure time in hours and multiply this by the exposure rate from scattered radiation, which is generally obtained from radiation-measuring equipment which reads in milliroentgens per hour. Using the figures in this example, the annual exposure time is:

$$\frac{55 \text{ films}}{\text{week}} \times \frac{1.2 \text{ secs}}{\text{films}} \times \frac{50 \text{ weeks}}{\text{year}} \times \frac{1 \text{ min}}{60 \text{ secs}} \times \frac{1 \text{ hour}}{60 \text{ min.}} = \frac{55 \times 1.2 \times 50}{3600} =$$

$$\frac{55}{60} \text{ hours per year, or about one hour per year.}$$

The annual exposure is the product of the rate and exposure time, or

$$1200 \times \frac{55}{60} = 1100 \text{ mR/year} = \text{annual exposure.}$$

The general expression for calculating the annual exposure to scatter radiation in dental radiography is:

$$\text{Annual exposure in mR} = \frac{\text{films}}{\text{week}} \times \frac{\text{seconds}}{\text{films}} \times \frac{\text{weeks}}{\text{year}} \times \frac{\text{hours}}{\text{second}} \times \frac{\text{mR}}{\text{hr}} \text{ (exposure rate).}$$

Since the national average exposure time to scatter radiation is about one hour per year, a good approximation of the exposure is equal to the number of mR read off a meter which has been calibrated to record in mR/hr.

APPENDIX F

SIMPLE PROCEDURE FOR MAKING A LEAD DIAPHRAGM FOR A DENTAL X-RAY MACHINE

It is recommended that the area of the X-ray beam at the tip or end of the dental X-ray pointing device (with a round, square or rectangular base) be limited to a diameter of 2.75 inches. If the diameter exceeds 2.75 inches, it should be corrected by collimation to the recommended diameter to eliminate unnecessary radiation.

Restriction of the X-ray beam is accomplished by the use of a lead disc which has a hole in the center of the appropriate size. The outside diameter of the disc should be identical with the outside diameter of the aluminum filter. It is ordinarily fitted inside the removable pointing device at the same location as the filter. The diameter of the hole in the disc will vary with different machines because of variable distances between the lead discs and the sources of radiation.

To check on the beam size of your X-ray machine, take five standard dental films and join them together in the form of a cross (+) on a suitable surface. Overlap the films with a piece of wire so as to simplify repositioning after development. The pointing device is positioned perpendicular to the films and in the center of the cross. Expose for one second. Develop and reposition. Measure the diameter of the exposed area to obtain the beam size.

If the beam size needs correction, then a suitable beam restricter, collimator, or lead diaphragm should be purchased and installed. If it cannot be purchased, one can easily be made.

Since X-ray machines will vary in the size of the beam restricter required, it is necessary to calculate the size individually. This can be done by the following two methods:

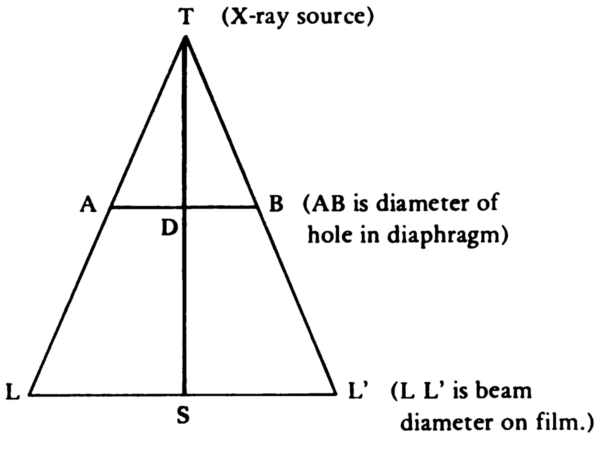

T (X-ray source)
A
B (AB is diameter of hole in diaphragm)
D
L
L' (L L' is beam diameter on film.)
S

Figure E1. X-ray beam

Method 1.

Step 1. Obtain a four-pound lead sheet (1/16 inch thick) from a plumber's shop. Measure the inside diameter of the pointer cone to obtain the outside diameter of the lead diaphragm. A circle of the proper diameter should be inscribed on the lead sheet with a compass. Cut the lead disc with a pair of shears. Position the disc in the cone and screw the cone back into the X-ray head.

Step 2. Two measurements are necessary.

1. Measure AB. This is the diameter of the hole in the diaphragm. See Figure E1.
2. Measure L L'. This is the beam diameter as measured on the exposed film.

If the beam diameter at L L' is not 2.75 inches, a new diaphragm must be made with the correct hole size. It may be calculated as follows:

$$\frac{\text{Old AB}}{\text{Old L L'}} = \frac{\text{New AB}}{\text{New L L'}}$$

where old AB and old L L' are the measured values and new L L' is equal to 2.75 inches, then

$$\text{New AB} = \frac{\text{Old AB} \times 2.75}{\text{Old L L'}}$$

Lets assume some values so that we can make an actual numerical calculation. Assume that AB = 1.5 inches and L L' = 3.5 inches, then

$$\text{the New AB} = 1.5 \times 2.75/3.5 = 1.18 \text{ inches}$$

Step 3. Inscribe a circle of 1.18 inch diameter in the center of a new lead disc. Cut out the circle with a suitable knife. Insert the diaphragm into the cone (utility wax is sometimes necessary to hold the disc in place). Screw cone into the X-ray machine. Proper collimation should be the result. To check the results, expose and develop another five X-ray films and measure the beam size.

Method 2.

Step 1. Obtain a four pound lead sheet (1/16 of a inch thick) from a plumber's shop. Measure inside diameter of pointer cone to obtain outside diameter of lead diaphragm. A circle of the proper diameter should be inscribed on the sheet with a compass, and the lead disc can easily be cut with a pair of shears. The disc is positioned in the cone to assure proper fit, and the cone screwed back into X-ray head.

Step 2. Place diaphragm in base of removable cone and then screw cone back into X-ray head. Using a ruler gauge the distance from diaphragm position to end of cone. Subtract this measurement from the pre-determined focal spot to tip of cone readings. These are listed as follows:

Ritter	7 in.	XRM	5.5 in.
General Electric	8 in.	Fischer	7 in.
Weber	6.25 in.	All Others	7 in.

These figures are transferred to the drawing (see Figure E1).

Step 3. Using simple Geometry you can now calculate the diameter. Definitions from Figure II.

TS - distance from target to end of pointing devise (cone).

TD - distance from target to diaphragm (beam restricter).

AB - diameter of lead diaphragm hole.

Calculations:

$$\frac{AB \;-\; LL'}{TD \;-\; TS} \quad \text{or} \quad AB = TD \;\text{x}\; \frac{LL'}{TS}$$

Example: Measured distance of DS = 4 inches.

Then assuming a Ritter machine TS = 7

$\therefore$ TD = 3 inches (TS - DS)

LL' = 2.75 desired beam size at end of cone.

$AB = 3 \;\text{x}\; \frac{2.75}{7}$ AB = 1.2 inches diameter.

Step 4. Using diameter calculated (AB), then inscribe a circle in the central portion of the lead diaphragm. Cut this section out with a knife. The lead diaphragm is repositioned in the cone, and the cone is screwed back on the tube head. Sometimes utility wax is necessary to hold the diaphragm firmly in position.

APPENDIX G

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